

**Sistemas Interativos Tangíveis e Processos de  
Mediação Tecnológica: Hipóteses sobre Agência,  
Significação e Cognição a partir da Investigação  
do MIT Tangible Media Group**

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*Aos meus pais.*

# **SISTEMAS INTERATIVOS TANGÍVEIS E PROCESSOS DE MEDIAÇÃO TECNOLÓGICA: HIPÓTESES SOBRE AGÊNCIA, SIGNIFICAÇÃO E COGNIÇÃO A PARTIR DA INVESTIGAÇÃO DO MIT TANGIBLE MEDIA GROUP**

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**PALAVRAS-CHAVE:** interação humano-computador, interfaces tangíveis, mediação tecnológica, Festival Ars Electronica

A presente dissertação toma a investigação em sistemas de interação tangível do MIT Tangible Media Group como objeto, a pretexto da sua inclusão na edição de 2016 do Festival Ars Electronica, sob o tema *Radical Atoms: The Alchemists of Our Time*. Pretende-se compreender quais os pontos de contato da investigação do grupo com os estudos dos media, de forma a localizar a sua relevância para a programação do festival. O enquadramento nos estudos dos media é feito pela localização de um conjunto de termos-chave no trabalho do grupo, os quais evocam questões afetas à fenomenologia, filosofia da tecnologia e mediação tecnológica. Conclui-se que estes sistemas de interação tangível ativam processos particulares de constituição de agência, significação e cognição. Na ausência de outros materiais que explorem estas relações no contexto do festival, a dissertação apresenta-se assim como complemento à leitura do tema *Radical Atoms: The Alchemists of Our Time*.

KEYWORDS: human-computer interaction, tangible interfaces, technological mediation, Ars Electronica Festival

This dissertation thesis takes the research of the MIT Tangible Media Group as its object, by occasion of its inclusion in the 2016 edition of Ars Electronica Festival under the theme *Radical Atoms: The Alchemists of Our Time*. The aim is to understand what are the common points between the group's research and media studies, in order to locate this object's relevance to the festival programming scope. The framing within media studies is done by surveying a set of keywords from the group's research, which evoke topics from phenomenology, philosophy of technology and technological mediation. It's concluded that these tangible interactive systems activate specific processes of agency, signification, and cognition. Given the lack of materials which explore these relationships within the context of the festival, the dissertation presents itself as a supplement to the reading of the *Radical Atoms: The Alchemists of Our Time* theme.

## ÍNDICE

I. Introdução .....	6
II. Identificação de projetos: dos <i>Tangible Bits</i> aos <i>Radical Atoms</i> .....	11
III. Descrição da recolha e análise de termos .....	21
IV. Localização dos termos seleccionados no contexto dos estudos dos media .....	24
IV. 1. Ubíquo .....	25
IV. 2. Superfície .....	33
IV. 3. Forma .....	40
V. Sistemas de interação tangível e processos de mediação tecnológica: discussão sobre agência, significação e cognição .....	48
VI. Conclusão .....	57
Bibliografia .....	60
Lista de Figuras .....	66
Anexo 1: <i>Corpus</i> de Análise .....	67
Anexo 2: Palavras-chave — Vista geral .....	67
Anexo 3: Termos seleccionados — Palavra-chave em contexto .....	75

## I. INTRODUÇÃO

A ideia de interação tangível não constitui algo de essencialmente novo no contexto da interação humano-computador, enquanto o campo que estuda e projeta formas de relação entre utilizadores e computadores. Basta um breve exercício de arqueologia para demonstrar que as primeiras formas de computação foram pautadas pelo carácter físico dos processos: antecédidos pelos sistemas de cálculo simples, os primeiros computadores programáveis são conceptualizados ainda no século XIX com recurso a cartões perfurados, uma técnica já utilizada nos teares mecânicos de *jacquard*<sup>1</sup>. Não obstante, o desenvolvimento subsequente concentrou a interação na comunicação visual do ecrã (*output*), auxiliada por periféricos (*input*). Senão recentemente, a tecnologia de consumo assistiu à radical miniaturização dos componentes e uma nova abordagem aos sistemas de *input/output*, permitindo que a experiência de utilizador adquira o grau de mobilidade espacial que era inviabilizada por tecnologias anteriores. Neste sentido, grandes corporações dedicam larga parte do investimento na Investigação e Desenvolvimento (I&D) de tecnologias como a Realidade Virtual, Realidade Aumentada, *Internet of Things*, *Connectables*, *Wearables*<sup>2</sup>..., todos estes participando na constituição de complexas paisagens informacionais que afetam a experiência quotidiana. Note-se, contudo, que uma larga parte destas propostas tende a centralizar o controlo dos processos nos dispositivos móveis, o que pode ser entendido como uma limitação ao campo de possibilidades para a produção e experiência tecnologicamente mediadas dos ambientes quotidianos.

A presente dissertação assume justamente a necessidade de explorar outras formas de produção tecnologicamente mediada do espaço que contrariam a lógica das tecnologias mencionadas acima, as quais são pautadas por (a) métodos de simulação ou

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<sup>1</sup> Cf., Plant, S. (1997). *Zeros ones: women, cyberspace and the new sexual revolution*. London: Fourth Estate.

<sup>2</sup> Exemplos incluem o Microsoft HoloLens (realidade mista), o Intel RealScape (realidade aumentada), Google Glass (realidade aumentada), o Oculus Rift (realidade virtual), o Samsung Gear VR (realidade virtual), Apple Watch (*wearable*), Google Contacts (*wearable*).

(b) tecnologias sensoras distribuídas, concentrando o respetivo controlo em dispositivos móveis. Deste espaço de possibilidades, é exercido foco sobre os sistemas de interação tangível, abrindo a discussão sobre os processos de mediação tecnológica em que participam. Significa isto que a presente dissertação não se irá debruçar sobre a descrição intensiva das técnicas e processos empregues no desenvolvimento dos sistemas de interação apresentados. Muito pelo contrário, estes sistemas serão analisados em função dos seus possíveis cenários de uso e pelos modos como, no contexto desse uso, estas tecnologias informam as relações entre os utilizadores e o mundo.

Para o efeito, toma-se como objeto de estudo o trabalho do Tangible Media Group. O grupo de investigação, parte integrante do Massachusetts Institute of Technology Media Lab (MA, EUA), foi fundado em 1995 por Hiroshi Ishii (*Jerome B. Wiesner Professor of Media Arts and Sciences* e *Associate Director* do MIT Media Lab) e completa duas décadas de investigação na potencial integração contínua entre pessoas, informação digital e o ambiente físico através dos dois grandes projetos *Tangible Bits* e *Radical Atoms*. O primeiro destes projetos parte da premissa de que enquanto utilizadores, dispomos de um leque de ações físicas e espaciais inatas que vem a ser largamente ignorado pelas interfaces atuais, para assim propor sistemas em que os processos de interação são controlados através da manipulação de objetos quotidianos. Já o projeto subsequente, *Radical Atoms*, defende que o futuro da interação tangível consiste no desenvolvimento de materiais “inteligentes” com o mesmo grau de plasticidade que píxeis num ecrã, assim especulando sobre um cenário de radical integração entre átomos, *bits* e utilizadores.

O MIT Media Lab, fundado e dirigido por Nicholas Negroponte, surgiu no seguimento do Architecture Machine Group, criado em 1967, com o propósito de desenvolver uma máquina capaz de simplificar o trabalho de projeto. Muito embora a Architecture Machine nunca tenha sido concretizada, dela resultaram um conjunto de sub-produtos que definiram a lógica e âmbito da pesquisa desenvolvida posteriormente no Media Lab e, inclusivamente, o tipo de preocupações que ocupa o Tangible Media Group. Algum do seu trabalho inicial permitiu o desenvolvimento do *Computer Aided Design* (CAD), do *Spatial Data Management System*, que concretizou a metáfora da



secretária posteriormente empregue pelas interfaces gráficas, e ainda do *Media Room*, que traduziu a metáfora da secretária à escala de uma sala, no contexto da qual o utilizador podia manipular a informação usando comandos de voz (Brand, 1987, 138-139).

Desde a data da sua criação que a atividade do MIT Media Lab encara a inevitável e recorrente redefinição dos media; parte do fascínio da investigação ali desenvolvida reside na projeção de cenários futuros, numa determinação quase romântica das possibilidades criativas deste processo. Na gíria do laboratório, o lema é “Demo or Die”, ou como refere Nicholas Negroponte: «We write about what we do... but we don't write unless we've done it.» (Brand, 1987, 4); ou seja, mais do que desenvolver exercícios académicos de reflexão sobre estas tecnologias, é necessário demonstrar e publicitar o trabalho desenvolvido. Esta é justamente a natureza do trabalho do Tangible Media Group, que prima por um intenso trabalho de produção académica e desenvolvimento de protótipos demonstrativos das ideias do grupo.

A transdisciplinarietà própria ao trabalho do Tangible Media Group foi recentemente referenciada pelo Festival Ars Electronica, evento promovido pelo instituto austríaco Ars Electronica GmbH numa base anual. Na sua última edição (8 — 12 de Setembro de 2016), o Festival apresentou-se sob o tema *Radical Atoms: The Alchemists of Our Time*. A programação do Festival cruzou uma retrospectiva do trabalho do Tangible Media Group com um conjunto mais vasto de objetos artísticos no espaço das *media and electronic arts*, numa exposição bipartida: a seleção de projetos apresentada no conjunto *Radical Atoms* é localizada no seio dos temas indicados acima, através do diálogo com as obras que constituem o conjunto *The Alchemists of Our Time*.

O título torna evidente a intenção de abordar estes objetos não apenas no âmbito da inovação tecnológica que propõem, mas primeiramente pelo tipo de práticas e usos que sugerem, assim oferecendo pretexto para a consideração destes objetos à luz dos estudos dos media, em particular, na articulação entre os temas da fenomenologia, filosofia da tecnologia e mediação tecnológica. Apesar da sugestão evidente pelo tema, os materiais produzidos pelo festival que foram consultados — catálogo, comunicados de imprensa, textos do website do Festival ([www.aec.at/radicalatoms](http://www.aec.at/radicalatoms)) — não oferecem nenhuma leitura de fundo sobre o enquadramento do trabalho do Tangible Media Group

nos estudos dos media. Deste modo, a presente dissertação é motivada pela concretização desse espaço de discussão, oferecendo assim um contributo para a leitura da linha de investigação *Radical Atoms* a pretexto da sua utilização como tema da edição de 2016 festival.

Importa ressaltar que, desde a sua criação até ocasião da exposição (1997 — 2016), o Tangible Media Group produziu centenas de objetos, dos quais apenas um conjunto muito reduzido é mostrado na Ars Electronica. De forma a oferecer uma vista compreensiva da seleção mostrada, a exposição é contextualizada por uma cronologia que cobre o período compreendido entre 1997 e 2016. É precisamente esta cronologia, publicada no catálogo do Festival, que delimita e estrutura o *corpus* de análise da presente dissertação. De entre o material disponível no *website* do grupo (<https://tangible.media.mit.edu>), foi selecionado um artigo científico por cada objeto elencado na cronologia, procurando dar prioridade, sempre que possível, ao artigo que serve o propósito de introdução do objeto no seio da comunidade científica especializada. Obtendo esta amostra, pretendeu-se determinar um conjunto de termos centrais à investigação do Tangible Media Group que permita localizar o trabalho do grupo no contexto dos estudos dos media.

Tendo a investigação do Tangible Media Group como objeto e a Ars Electronica como contexto e critério para a definição do *corpus* de análise, a dissertação coloca as seguintes questões de trabalho:

- (1) Como se articulam os dois principais projetos do Tangible Media Group, *Tangible Bits* e *Radical Atoms*, em relação à classificação proposta pela Ars Electronica?
- (2) Quais são os termos-chave que caracterizam o trabalho do Tangible Media Group e que permitem estabelecer ponto de contacto com os estudos dos media?
- (3) Quais as implicações do trabalho do Tangible Media Group para os processos de mediação tecnológica, tendo em consideração os processos de agência, significação e cognição ativados por estes sistemas de interação tangível?

De modo a responder a estas questões, o Capítulo II começa por detalhar a natureza da investigação do Tangible Media Group e a articulação entre os projetos

*Tangible Bits* e *Radical Atoms*, sendo apresentadas sucintamente as sete categorias e os 31 projetos que a Ars Electronica propõe para caracterizar a investigação do Tangible Media Group, no período compreendido entre 1997 e 2016. O Capítulo III, por seu turno, esclarece os critérios utilizados para a seleção da amostra, descreve a técnica usada para recolha de um conjunto de termos que permitem a análise da produção teórica do Tangible Media Group em função dos temas da mediação tecnológica. A partir desta recolha e análise são isolados três termos pela possibilidade que abrem de localizar o trabalho do Tangible Media Group no contexto dos estudos dos media. São escolhidos os seguintes: “ubíquo”, “superfície” e “forma”, dados os pontos de contacto que estabelecem com os discursos da fenomenologia, filosofia da tecnologia e mediação tecnológica. Uma vez isolados estes termos, o Capítulo IV apresenta uma revisão teórica em torno dos mesmos, no contexto dos estudos acima referidos. Considerando que o âmbito deste trabalho procura sublinhar os usos e práticas dados a estas tecnologias, na medida em que informam a experiência do real, dos termos analisados releva a discussão sobre a mediação tecnológica implicada nestes sistemas de interação tangível. Assim, o Capítulo V propõe um enquadramento para a análise destes objetos em função da co-constituição de agentes, dos processos de significação que ativam e dos processos cognitivos decorrentes dessas relações, as quais remetem para uma ideia de contiguidade entre a plasticidade da mente e do real.

## II. IDENTIFICAÇÃO DE PROJETOS: DOS *TANGIBLE BITS* AOS *RADICAL ATOMS*

Bastante influenciado pelo contexto do MIT Media Lab, o Tangible Media Group foi impulsionado por um conjunto de trabalhos seminais como o *TeamWorkStation* (1990)<sup>3</sup>, um espaço de colaboração remota que permite o desenho em tempo real por múltiplos agentes distribuídos no espaço, ou o *ClearBoard* (1993)<sup>4</sup>, que deteta sugestões visuais e a direção do olhar de forma a facilitar a comunicação entre utilizadores remotos. Contudo, o momento-chave para a visão do Tangible Media Group remonta à ACM CHI'97 — Human Factors in Computing Systems Conference, na qual foi comunicada publicamente a proposta do projeto *Tangible Bits*. Os autores Hiroshi Ishii e Brygg Ullmer apresentaram o artigo “Tangible Bits: Towards Seamless Interfaces between People, Bits and Atoms”, o qual constituiu um marco na pesquisa em interação tangível humano-computador:

«Current GUI-based HCI displays all information as “painted bits” on rectangular screens in the foreground, thus restricting itself to very limited communication channels. GUIs fall short of embracing the richness of human senses and skills people have developed through a lifetime of interaction with the physical world» (Ishii e Ullmer, 1997, 7).

O argumento de “Tangible Bits...” começa por valorizar o tipo de experiência oferecida pelo desenho e riqueza material de artefactos científicos antigos, para reclamar a necessidade de restituir o mesmo tipo de experiência háptica para o desenvolvimento em interação humano-computador. Em resposta ao modo como a cultura perpetuou a cisão entre o espaço físico e o ciberespaço como “mundos paralelos”, a interface tangível é proposta como a possibilidade do seu entrelaçamento. De forma a propor uma alternativa à representação visual dos processos de interação oferecida pela GUI, Ishii e Ullmer assentam a sua proposta inicial em três

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<sup>3</sup> Desenvolvido com Kazuho Arita, nos NTT Human Interface Laboratories, Japão.

<sup>4</sup> Desenvolvido com Minoru Kobayashi nos NTT Human Interface Laboratories, Japão.

características-chave: (1) ativação de superfícies físicas como interfaces; (2) a integração uniforme de informação digital (*bits*) e objetos palpáveis quotidianos<sup>5</sup> (átomos) e (3) o uso de media ambiente<sup>6</sup>. O trabalho de Ishii e da sua equipa é influenciado por trabalhos prévios, de entre os quais se destacam a computação ubíqua e a realidade aumentada.

A computação ubíqua, assim como premeditada por Mark Weiser e pela sua equipa no Palo Alto Research Center (PARC), assenta na crescente portabilidade, comunicação e sensibilidade ao contexto dos sistemas computacionais, desenhando sistemas de distribuição generalizada de computação capazes de se integrar a existência quotidiana na condição de fenómenos de fundo (*background*) (Weiser, 1991). A realidade aumentada, na altura um campo de pesquisa ainda recente, é relevante pela sua proposta de extensão da perceção do espaço físico através de informação digital em tempo real e em função do contexto, frequentemente recorrendo a dispositivos que abordam diretamente o sentido da visão, como óculos, *head-mounted displays* ou *smartphones*. Por seu turno, a noção de *Tangible Bits* demarca-se do trabalho anterior no sentido em que não pretende a distribuição generalizada dos computadores *per se*, mas o estudo das possíveis formas de integração entre os processos digitais e as características físicas dos ambientes e artefactos quotidianos — superfícies, objetos, espaços, instrumentos — de forma a que a interação com os media digitais não se restrinja necessariamente à representação gráfica da informação, mas utilize as propriedades físicas destes elementos como meio de expressão e comunicação.

Alguns dos protótipos que acompanham esta proposta inicial incluem o *metaDESK*, o *ambientROOM* e o *transBOARD*. O *metaDESK* parte da transposição para

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<sup>5</sup> Do original, *graspable objects*. Apesar de não encontrar tradução adequada na língua Portuguesa, a terminologia em questão é relevante pois convoca um outro trabalho académico relevante: *Graspable User Interfaces*, a dissertação de doutoramento de George W. Fitzmaurice, submetida à Universidade de Toronto em 1996. Neste trabalho não é usado o termo *tangible* mas sim *graspable*. O autor justifica o uso do termo com base no seu duplo sentido: *to grasp an object* no âmbito físico e *to grasp a concept* no âmbito cognitivo. Pela proximidade às questões cognitivas, este trabalho será especialmente convocado na última seção da presente dissertação.

<sup>6</sup> Do original, *ambient media*. Terminologia introduzida na dissertação de Craig Wisnesky, *The Design of Personal Ambient Displays*, um dos primeiros trabalhos conferentes de grau académico produzido dentro do contexto do Tangible Media Group. *Ambient media* designa as formas que empregam luz e/ou som ambientes, fluxo de ar, movimento de água, ou movimento físico como formas de periféricas de exibição de informação, que se situam no plano de fundo da atenção do utilizador.

o ambiente físico do conjunto de metáforas nas quais se baseia o sistema da GUI; a superfície resultante permite o *output* e *input* simultâneos de informação. Sobre esta são dispostos objetos, designados *tokens*, que incorporam os vários dispositivos metafóricos (objetos, ícones, pegas, janelas), que podem ser movidos sobre a informação projetada, de modo a desempenhar as mesmas funções dos seus análogos gráficos (Ishii e Ullmer, 1997, 4). O *ambientROOM*, por seu turno, pretende complementar o tipo de experiência do *metaDESK* ao enfatizar o uso de media ambiente (luz e sombra, som, fluxo de ar e água) como forma de comunicar informação na periferia da percepção humana, assim enriquecendo a experiência sensorial e cognitiva (*ibid.*, 5). Finalmente, o *transBOARD* visa aplicar as tecnologias anteriormente descritas a um ambiente de colaboração remota.

Nos seus traços gerais, estes três produtos sumariam o percurso subsequente da investigação desenvolvida no contexto da visão *Tangible Bits*. Esta dependeu frequentemente deste tipo de *layouts* em que objetos discretos são dispostos sobre uma superfície e tratados como recipientes da informação digital, sendo que estes sistemas dependem invariavelmente de mecanismos de *input*, *output* e *feedback* com o mínimo de latência possível, de modo a assegurar a sensação de interação. Porém, dada a rigidez própria dos átomos, estes *tokens* carecem da fluidez com que píxeis num ecrã representam diferentes tipos de informação, o que gera alguma inconsistência relativamente aos modelos digitais.

Por seu turno, o *Radical Atoms* parte das limitações encontradas pelo seu precursor, de modo a definir o passo seguinte no contexto da interação tangível. Procurando alternativas a objetos discretos, toma em seu lugar materiais moldáveis como formas contínuas de *input*. Para os investigadores do Tangible Media Group, os desenvolvimentos em nanotecnologias e “materiais inteligentes” abrem possibilidades concretas para a aproximação ao grau de maleabilidade dos píxeis, ao mesmo tempo que é mantida a relação háptica e gestual com o material. As tecnologias utilizadas viabilizam o *input* bidirecional para controlo do aspeto material por via do modelo computacional de base que determina a sequência de ações e resultados possíveis. Tal como no *Tangible Bits*, a visão dos *Radical Atoms* assenta em três características-chave: (1) os seus objetos devem transformar a sua forma conforme o modelo computacional

de base, (2) devem conformar mediante as restrições e possibilidades introduzidas pelo contexto e pelas ações do utilizador e (3) devem ainda informar o utilizador das capacidades dinâmicas de transformação que permitem<sup>7</sup> (Ishii et al., 2012, 45). Ressalve-se que o âmbito da investigação do Tangible Media Group não se concentra no desenvolvimento exaustivo de novos materiais que concretizem em pleno esta visão, mas sim na conceção de cenários hipotéticos de interação, de modo a demonstrar a visão do grupo para a redefinição futura dos media. Os objetos produzidos no contexto dos *Radical Atoms* apresentam-se assim como sucessivas aproximações a um horizonte no qual futuros materiais hipotéticos permitem concretizar interfaces com um elevado grau de maleabilidade, atuação e capacidade expressiva. Tomando as palavras de Daniel Leithinger (*Research Affiliate*, MIT Tangible Media Group) em entrevista à Ars Electronica:

«(...) on the one hand there will be objects that we'll design by ourselves, that will be individually done. That means there will be the professional designers, but also input from the consumer. And therefore we need computers. And on the other hand there will be changeable objects that will grow with us. These objects, let's say a table, will have the possibility to communicate with me, like a living thing. This is only one of many possible futures that we're thinking about at the moment.» (Ars Electronica, 2016)

Na medida em que o Tangible Media Group partilha a mesma filosofia do Media Lab, a sua abordagem é fortemente caracterizada pela orientação no sentido da confluência entre tecnologia, arte e design, ao mesmo tempo que pauta por investir na ampla comunicação e publicitação mediática da sua investigação. Deste modo, os produtos da sua pesquisa rapidamente se tornaram clássicos no contexto das *Media and Electronic Arts*, reclamando o seu lugar desde o laboratório ao museu. Não é portanto inusitado que o projeto *Radical Atoms* tenha servido de inspiração ao tema da última edição do Festival Ars Electronica, através do tema *Radical Atoms: The Alchemists of Our Time*. Como já foi referido, este tema desdobra-se numa exposição bipartida, que definiu o cerne da programação. De um lado, o conjunto *Radical Atoms* incluiu um conjunto de trabalhos que reflete o percurso do Tangible Media Group, sendo exibidos

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<sup>7</sup> Do original, *transform, conform e inform*.

os seguintes: *musicBottles*, *SandScape*, *Topobo*, *Perfect Red*, *inform*, *PneUI*, *LineFORM*, *JamSheets*, *biologic* e *ZeroN*, objetos que serão apresentados em maior detalhe adiante.

Por outro lado, *The Alchemists of Our Time* reúne um conjunto de criações recentes, de caráter assumidamente artístico, que entra em diálogo com estes objetos, propondo a sua leitura em função do contexto de exibição e do que é o âmbito do festival. Alguns trabalhos de destaque incluem: o *Sculpture Factory*, de Quayola, no qual um *robot* a escala industrial esculpe variações infinitas e algoritmicamente geradas da obra-prima clássica *Laocoonte e os seus filhos*; *ASSISlb* de Thomas Schmickl, utiliza inteligência artificial para programar uma sociedade de *robots* capazes de desenvolver canais de comunicação com sociedades animais e assim estudar os fatores de sustentabilidade dos ecossistemas; *Beyond Prototyping*, o projeto de Jussi Ängeslevä subverte a divisão entre o design de produto e o processo de produção, de forma a conceber objetos com base em processos de design algorítmico cujo significado transcenda a mera funcionalidade; *Urpflanze*, de Susana Soares, parte do estudo genético sobre a morfologia das plantas para conceber modificações que ofereçam soluções de adaptabilidade para problemas como as alterações climáticas ou a insuficiência nas cadeias de produção alimentar; o *Skinterface*, de Charlotte Furet, Catherine Ka Hei Suen, Andre McQueen e George Philip Wright, concebe uma interface do tipo “segunda pele” capaz de transmitir a interação virtual em estímulos hápticos distribuídos sobre o corpo; *Mycotex*, apresentado pelo NEFFA, consiste na utilização de compósitos flexíveis que combinam têxteis e material orgânico (*mycelia*); o *Project Florence*, de Helene Steiner, Paul Johns, Asta Roseway, Chris Quirk, Sidhant Gupta e Jonathan Lester, tira partido da sensibilidade das plantas a diferentes frequências de luz de modo a estimular a responsividade da planta, comparando estes sinais com os processos naturais da linguagem e assim abordando a planta como um ser vivo e reativo, abrindo novas perceções de como interagimos com o ambiente natural.

A relação entre os dois conjuntos posiciona o trabalho do Tangible Media Group no contexto mais lato da transformação profunda que atravessa as práticas atuais de I&D, pautada pelo abandono de práticas e metodologias tradicionais em prol de novos espaços, enquadramentos e colaborações. A interação entre arte, ciência e



tecnologia vem a alterar significativamente o modo como olhamos para os produtos destas investigações conjuntas. De entre os resultados, emergem novas visões sobre o papel social da ciência ou sobre a relação entre natureza e tecnologia (Ars Electronica, 2016, 2).

Dado que o número de objetos exibidos no Festival foi bastante reduzido relativamente ao que é a produção imensa do Tangible Media Group, a cronologia que acompanhou o catálogo da exposição permite localizar os objetos selecionados no contexto maior da produção do grupo, assim como oferece uma classificação compreensiva da transição entre os projetos *Tangible Bits* e *Radical Atoms*. A mesma cronologia confere, no contexto da presente dissertação, limite e estrutura ao *corpus* de análise, apontando sete categorias, ao longo das quais se distribui uma seleção de 31 objetos<sup>8</sup>: Table Top Tangibles, Deformable Tangibles, Dynamic Shape Displays, Programmable Materials, Actuated Table Top Tangibles, Levitating Materials, Kinetic Materials. No esquema que se reproduz a seguir, os produtos dos projetos de investigação do Tangible Media Group são organizados em termos evolutivos desde “static/passive” em direção a “active/kinetic”, tendo a categoria “radical” como horizonte.

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<sup>8</sup> Muito embora a cronologia original mapeie um total de 32 projetos, a presente recolha ignora a versão do projeto inFORM criada especialmente para a exibição no Cooper Hewitt Museum (2015), sendo o projeto essencialmente idêntico à versão inicial.

**Evolução: dos *Tangible Bits* aos *Radical Atoms*** (reproduzido a partir da cronologia original, publicada no catálogo do Festival Ars Electronica 2016):

Static / passive	(1) Table Top Tangibles				(2) Deformable Tangibles	
	musicBottles (2001)	MetaDesk (1997)	Urp (1998/1999)	Sensetable (2001)	Illuminating Clay (2002)	SandScape (2002)
Active / kinetic	(3) Dynamic Shape Displays					
	Relief (2009/2011)	Recompose (2011)	SUBLIMATE (2013)	inFORM (2013/2014)	TRANSFORM (2014/2015)	
	Kinetic Blocks (2015)	Materiable (2016)				
	(4) Programmable Materials					
	Jamming UI (2012)	Pne UI (2013)	jamSheets (2014)	OptiElastic (2014)	bioLogic (2014/2015)	uniMorph (2015) Cilllia (2016)
	(5) Actuated Table Top Tangibles			(6) Levitating Materials		
	PSyBench (1998)	Actuated Workbench (2002)	PICO (2007)	ZeroN (2011)		
	(7) Kinetic Materials					
	inTouch (1998)	curlyBot (2000)	Topobo (2004/2006 /2008)	Kinetic Sketchup (2010)	Bosu (2010)	LineFORM (2015) ChainFORM (2016)
	Radical Atoms	Phase Shift		Programmable materiality Levitation		Biological symbiosis Self-assembly

(1) **Table Top Tangibles**, designa o conjunto de aplicações definido pelo uso de objetos como contentores de informação digital, que são dispostos sobre uma superfície plana equipada com um mecanismo de *input* e *output* de informação visual. A primeira destas aplicações, o *metaDESK* (1997), assenta num sistema de *tokens*, sendo o sucessor direto dos experimentos de Ishii em ambientes colaborativos remotos, que antecedem o estabelecimento do Tangible Media Group: *TeamWorkStation* (1990) e o *ClearBoard* (1993). O *musicBottles* (2001), consiste numa instalação em que um conjunto de garrafas e as suas tampas são utilizadas como controladores de várias pistas de sons. O *Urp* (1998/1999) utiliza o mesmo tipo de *layout* para criar uma estação de trabalho para auxílio ao planeamento urbanístico. O *Sensetable* (2001), por seu turno, expande as possibilidades dos *tokens*, com a adição de controladores e reguladores.

(2) **Deformable Tangibles**, ao invés de utilizar objetos discretos, combina os mesmos sistemas I/O dos Table Top Tangibles com materiais que suportam deformação direta, incluindo argila, no caso do *IlluminatingClay* (2002) e micro contas de vidro no caso do *SandScape* (2002). Ambos constituem estações de trabalho para a conceção de modelos topográficos em tempo real. Utilizando a intensidade da luz projetada sobre o material, é possível a conversão dos valores de radiância de superfície para cálculo da elevação.

(3) **Dynamic Shape Displays**, dá continuidade aos Deformable Tangibles. Os objetos *Relief* (2009/2011), *Recompose* (2011), *SUBLIMATE* (2013), *inFORM* (2013/2014), *TRANSFORM* (2014/2015), *Kinetic Blocks* (2015) e *Materiable* (2016) têm como denominador comum a utilização de matrizes de pinos como mecanismo para representação e manipulação de informação através de atuação direta e gestual. Todos eles oferecem formas de *input* e *output* físicas; salva-se como exceção o *SUBLIMATE*, cujas simulações dependem em larga parte de realidade aumentada, possibilitada através do uso de um ou mais *tablets*. As várias aplicações deste conjunto abrem a possibilidade de interação multi-utilizador, geralmente em ambiente de co-presença física.

(4) **Programmable Materials**, agrupa os objetos definidos pela utilização de materiais “inteligentes” que permitem atuação e *feedback* diretos através da maleabilidade dos seus componentes físicos, sendo aqueles que mais se aproximam do horizonte dos *Radical Atoms*. Dada a necessidade de explorar novos materiais, técnicas

e aplicações para concretizar esta visão, o conjunto selecionado sob esta categoria é pontuado por uma grande diversidade de objetos, marcados por uma forte abordagem transdisciplinar. O **Jamming UI** (2012) aplica o método de *pneumatic particle jamming* para permitir *feedback* háptico e dinâmico. De modo semelhante, o **PneUI** (2013) propõe a utilização de materiais atuados, de modo a que as suas estruturas estratificadas e dotadas de diferentes propriedades mecânicas ou elétricas possibilitam o *input* e o *output* através da alteração da sua forma. O **jamSheets** (2014) oferece uma aplicação do tipo de materiais referidos anteriormente, para o desenho de interfaces mais finas e leves. O **OptiElastic** (2014) introduz a integração de fibra ótica em compósitos maleáveis de modo a possibilitar tanto a deteção gestual assim como a iluminação do material. O **bioLogic** (2014/2015) propõe o desenvolvimento de um tecido de base orgânica para roupa desportiva com capacidades de deteção e regulação da temperatura corporal e transpiração. O **uniMorph** (2015) pretende simplificar o desenvolvimento de interfaces ultra finas, similares a filme, através das características termo-elétricas dos seus componentes. Finalmente, o **Cillia** (2016) procura desenvolver um método para a impressão tridimensional de micro-fibras que permitem conferir capacidades sensórias e atuantes a superfícies, através do seu carácter textural.

(5) **Actuated Table Top Tangibles**, designa o conjunto de objetos que dá seguimento o espaço de design aberto pelos Table Top Tangibles. O **PSyBench** (1998) expande as possibilidades de atuação e co-presença tangível, com o conceito de *Synchronized Distributed Physical Objects*. O **Actuated Workbench** (2002), por seu turno visa apurar o *feedback loop* necessário para assegurar a menor latência possível da sincronização remota dos objetos, aplicando para tal uma matriz magnética. Finalmente, o **PICO** (2007) aplica igualmente força eletromagnética para criar um sistema de simulação e planificação de redes de sinal móvel.

(6) **Levitating Materials**, trata-se do campo menos explorado de entre as categorias referidas, referindo somente um objeto na classificação de referência, o **ZeroN** (2011) abre a possibilidade da atuação manual e *feedback* bidirecional de um objeto, deslocando-o livremente no espaço tridimensional. A levitação do objeto é possível através de um sistema magnético.

(7) **Kinetic Materials**, categoriza um conjunto um pouco mais heterogéneo de objetos que exploram estados de expressão dinâmicos assim como no caso dos Programmable Materials, contudo fazem-no de forma modular. O *inTouch* (1998), trata-se de um sistema para comunicação interpessoal que explora as possibilidades hápticas para extensão da sensação de co-presença. O *curlyBot* (2000) e o *Topobo* (2004/2006/2008) permitem memorizar e reproduzir movimento físico como meio didático para a exploração de conceitos básicos de programação. O *Kinetic Sketchup* (2010) e o *Bosu* (2010) constituem *kits* modulares que propõem as ferramentas necessárias para as práticas de design futuras no contexto do *Radical Atoms*, oferecendo componentes para projetar o grau de maleabilidade, atuação e capacidade sensória desses artefactos. Por fim, os objetos *LineFORM* (2015) e *ChainFORM* (2016) exploram o espaço das *serpentine robotics* enquanto interface tangível.

### III. DESCRIÇÃO DA RECOLHA E ANÁLISE DE TERMOS

A cronologia e classificação explicitados acima delimitam e estruturam o *corpus* de análise da presente dissertação. De entre o vasto arquivo de materiais disponível no *website* do grupo (<http://tangible.media.mit.edu>)<sup>9</sup> foi selecionado um artigo científico por cada objeto referido na cronologia, procurando dar prioridade, sempre que possível, ao artigo que serve o propósito de introdução do objeto no seio comunidade científica especializada. O conjunto final, apresentado em maior detalhe no Anexo 1 da presente dissertação, agregou 257 páginas distribuídas pelos 31 artigos; estes oferecem a descrição concisa e detalhada dos processos e tecnologias empregues em cada objeto, considerando não apenas as exigências próprias à comunicação especializada de investigação científica, mas também o discurso característico do MIT Media Lab.

Num primeiro momento, foram elencadas todas as palavras-chave apontadas pelos próprios autores nos seus artigos, de modo a obter uma primeira vista geral sobre o *corpus* de análise e as palavras-chave mais relevantes, organizadas cronologicamente; esta grelha pode ser consultada no Anexo 2 da dissertação. Posteriormente, a leitura exhaustiva do material permitiu uma maior compreensão de como estas palavras-chave são abordadas no contexto da produção científica do grupo, assim viabilizando a escolha dos termos a tratar como pontos de contacto com os estudos dos media.

Findo o processo, foram isolados três termos: “ubíquo”, “superfície” e “forma”, considerando a sua proximidade aos estudos em fenomenologia, filosofia da tecnologia e mediação tecnológica, tal que a localização destes três termos no seio destas áreas de estudo permite uma abordagem compreensiva do trabalho do Tangible Media Group e da sua pertinência para o âmbito do Festival Ars Electronica. Neste sentido, foi feito o levantamento de todas as ocorrências destes termos no *corpus* de análise, de modo a compreender que noções dos estudos dos media são evocadas pelo trabalho do Tangible

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<sup>9</sup> As duas exceções são os artigos referentes ao *Bosu* e ao *Kinetic Sketchup*, os quais não se encontram disponíveis no *website* do Tangible Media Group e foram consultados diretamente a partir da base de dados da ACM, em <http://dl.acm.org>.

Media Group. Este levantamento pode ser consultado no Anexo 3 da presente dissertação.

Relativamente ao levantamento dos termos no *corpus* que constitui o Anexo 3, foram registadas as seguintes frequências, por ano:

Ano	Ubíquo		Superfície		Forma	
	F <sub>n</sub>	F <sub>x</sub>	F <sub>n</sub>	F <sub>x</sub>	F <sub>n</sub>	F <sub>x</sub>
1997	2	0,40	29	0,06	0	0,00
1998	0	0,00	3	0,01	0	0,00
1999	2	0,40	2	0,00	8	0,01
2000	0	0,00	7	0,01	5	0,01
2001	0	0,00	0	0,00	0	0,00
2002	0	0,00	89	0,19	5	0,01
2003	0	0,00	23	0,05	1	0,00
2004	0	0,00	0	0,00	0	0,00
2005	0	0,00	6	0,01	0	0,00
2006	0	0,00	0	0,00	5	0,01
2007	0	0,00	0	0,00	0	0,00
2008	0	0,00	0	0,00	0	0,00
2009	0	0,00	6	0,01	15	0,02
2010	0	0,00	21	0,04	16	0,02
2011	0	0,00	35	0,07	2	0,00
2012	0	0,00	15	0,03	74	0,09
2013	0	0,00	101	0,21	276	0,35
2014	0	0,00	34	0,07	49	0,06
2015	0	0,00	24	0,05	223	0,28
2016	1	0,20	81	0,17	116	0,15
Total	5	1,00	476	1,00	795	1,00

A tabela de frequências acima<sup>10</sup> indicou quais seriam os momentos do período compreendido entre 1997 e 2016 em que cada um dos termos assume uma maior relevância no trabalho do grupo. A título preliminar:

(1) “**Ubíquo**”: muito embora o termo registe um reduzido número de referências diretas no *corpus*, a ideia de ubiquidade perpassa a investigação do Tangible Media Group desde o primeiro momento, pela influência determinante do trabalho sobre computação ubíqua que Marc Weiser e a sua equipa desenvolveram no Xerox PARC. O termo “ubíquo” é referido em dois dos primeiros trabalhos do grupo, o *metaDESK* e o *musicBottles*, precisamente para referir o trabalho de Weiser; posteriormente, surge

<sup>10</sup> A tabela regista as frequências absolutas (F<sub>n</sub>) e relativas (F<sub>x</sub>) de ocorrência dos termos “ubíquo”, “superfície” e “forma”, no período compreendido entre 1997 e 2016.

ainda numa referência pontual ao *uniMorph*. Neste sentido, a primeira secção do Capítulo IV começa por sintetizar os pontos fundamentais da computação ubíqua para depois rever algumas noções centrais à fenomenologia.

(2) “**Superfície**”: é registado de forma mais ou menos consistente ao longo do *corpus*, registando dois grandes períodos de ocorrências: o primeiro deles entre 1997 e 2003 e o segundo entre 2010 e 2016, sendo estes dois momentos sinónimo de dois sentidos distintos do termo superfície. O primeiro momento coincide com o projeto *Tangible Bits*, no qual a ideia de superfície sugere uma área matematicamente codificada que permite o mapeamento de objetos para controlo dos processos digitais correspondentes, estando diretamente conotada com um mecanismo de controlo de posições variáveis dentro de um espaço limitado. Este uso do termo surge frequentemente em referência a objetos como o *metaDESK*, *Sensetable*, *Actuated Workbench*, *Illuminating Clay* e *Sandscape*. Já o segundo sentido em que o termo é usado respeita à possibilidade de atuação sobre a superfície dos objetos para interação com a informação digital. Esta segunda conotação do termo é frequente utilizada em referência a objetos como o *inFORM*, *PneUI*, *JamSheets* e *Cillia*. Dado que neste último caso o uso do termo “superfície” está diretamente ligado ao termo “forma”, a segunda secção do Capítulo IV ocupa-se da localização do conceito no âmbito sugerido pela primeira conotação.

(3) “**Forma**”, o terceiro termo selecionado regista a larga parte das suas ocorrências no período compreendido entre 2012 e 2016, sendo central ao projeto *Radical Atoms*. O seu uso respeita à capacidade de expressão material dinâmica destes sistemas de interação tangível, atuados mediante gestos sobre a superfície ou pela manipulação do material e mediante as possibilidades suportadas pelo seu modelo computacional de base. A larga parte das suas ocorrências respeitam os objetos *JammingUI*, *inFORM*, *Sublimate*, *PneUI*, *LineFORM*, *uniMorph*, *Kinetic Blocks*, *ChainFORM* e *Materiable*. A terceira secção do Capítulo IV passa assim a tratar algumas noções fundamentais sobre a expressão material dos objetos.



#### IV. LOCALIZAÇÃO DOS TERMOS SELECIONADOS NO CONTEXTO DOS ESTUDOS DOS MEDIA

Considerando que os termos analisados foram isolados em função da sua proximidade com os estudos dos media e, em particular, com a fenomenologia, filosofia da tecnologia e mediação tecnológica, o presente capítulo ocupa-se da clarificação destas relações ao longo das suas três secções.

O termo “ubíquo” aproxima a proposta de computação ubíqua às visões clássicas sobre fenomenologia e tecnologia, prosseguindo de encontro às teorias pós-fenomenológicas recentes; esta primeira secção permite mapear um conjunto de contributos de fundamentais para delimitar os temas dos estudos dos media que se afiguram relevantes para o tratamento da investigação do Tangible Media Group.

O termo “superfície”, como já foi visto anteriormente, serve de charneira entre os projetos *Tangible Bits* e *Radical Atoms*, articulação que se torna patente no duplo sentido com que o termo surge no *corpus* de análise: inicialmente, superfície respeita à disposição de objetos sobre uma superfície matematicamente codificada, acedendo a um sistema de correspondências entre cada instância material e cada instância digital; assim, estes sistemas são revistos na condição de dispositivos de ordenação do real. Posteriormente, já no contexto do projeto *Radical Atoms*, o uso do termo superfície já não remete para uma estrutura que comporta agentes, mas para uma superfície que se torna, ela mesma, agente nos processos interativos, na condição de área de *input* e *output* simultâneos. Este segundo uso do termo “superfície” conduz à terceira secção do capítulo, dedicada ao uso do termo “forma”; este termo é abordado para exploração das possibilidades de reconfiguração plástica destes objetos, colocando em causa a conceção de um real que se faz depender necessariamente da sua consistência espaço-temporal.

Importa ainda ressaltar que ao longo das três secções do próximo capítulo, todas as referências à recolha dos termos no contexto do *corpus* serão assinalados com o respetivo código, que assinala o termo a que refere e a posição na grelha de análise

reproduzida no Anexo 3 da dissertação (exemplo: **UB.1** respeita à primeira ocorrência do termo “ubíquo” ). As siglas utilizadas para cada termo são as seguintes: **UB** = “ubíquo”, **SP** = “superfície” e **FO** = “forma”.

#### IV. 1. Ubíquo

Brygg Ullmer é responsável por um dos primeiros trabalhos académicos que estabelece o âmbito de investigação do Tangible Media Group, nele apontando a pesquisa prévia que oferece contexto ao *Tangible Bits*. A sua dissertação, intitulada *Models and Mechanisms for Tangible User Interfaces* (1997), é desenvolvida no contexto do tema de investigação *Things That Think*, estabelecido pelo consórcio do MIT e que serviu de denominador comum a um conjunto de investigações marcadas pela ideia de objetos digitalmente aumentados. Ullmer aponta a computação ubíqua como um dos percursos da interação tangível. Introduzida pela investigação de Weiser et. al (1991) no Xerox PARC, a computação ubíqua começou expandir a área de exibição do ecrã a um conjunto de superfícies distribuídas e desenhadas à escala dos objetos quotidianos que nos acompanham para registo e consulta de informação: *pads*, que herdam a portabilidade de um caderno, ou quadros, inspirados nos *layouts* das salas de aula e salas de reunião. Ressalve-se que ubiquidade em si não é sinónimo da portabilidade dos aparelhos, mas emerge das suas possibilidades enquanto conjunto de pontos conectados em rede, que é simultaneamente sensível ao contexto.

Assim a pesquisa de Weiser et al. procurou explorar o modo como dispositivos computacionais podem ser distribuídos e integrados de forma “transparente” no ambiente físico, dissolvendo-se no tecido da vida quotidiana e nos processos de circulação simbólica ativados desde a modernidade: «The ability to represent spoken language symbolically for longterm storage freed information from the limits of individual memory. Today this technology is ubiquitous in industrialized countries. Not only do books, magazines and newspapers convey written information, but so do street signs, billboards, shop signs and even graffiti.» (Weiser, 1991, 3). Assim, a ubiquidade tecnológica traduz-se no seu eventual desaparecimento, efeito da psicologia humana e

do modo como a relação com estes artefactos determina a relação hermenêutica com o mundo<sup>11</sup>:

«Whenever people learn something sufficiently well, they cease to be aware of it. When you look at a street sign, for example, you absorb its information without consciously performing the act of reading. Whenever people learn something sufficiently well, they cease to be aware of it. When you look at a street sign, for example, you absorb its information without consciously performing the act of reading. Computer scientist, economist and Nobelist Herbert A. Simon calls this phenomenon "compiling"; philosopher Michael Polanyi calls it the "tacit dimension"; psychologist J. J. Gibson calls it "visual invariants"; philosophers Hans Georg Gadamer and Martin Heidegger call it the "horizon" and the "ready-to-hand"; John Seely Brown of PARC calls it the "periphery"» (Weiser, 1991, 3).

Weiser sugere assim que a sua proposta para a computação ubíqua dialoga com alguns dos pensadores chave do século XX. De entre os nomes acima mencionados e tendo em consideração o objeto da presente dissertação, são revisitadas as posições sobre a fenomenologia de Karl Jaspers e Martin Heidegger, prosseguindo de encontro à proposta pós-fenomenológica de Don Ihde. As duas primeiras posições partem do reconhecimento de que, até ao século XVIII, o papel da tecnologia na sociedade havia sido particularmente definido e limitado no seu poder, assentando na força humana ou animal. Contudo, a Revolução Industrial foi sinónima da transição profunda nos modos de produção, no sentido em que os métodos de controlo e transformação dos recursos naturais para consumo humano foram exponencialmente aumentados pela tecnologia

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<sup>11</sup> Segundo Ishii, Marc Weiser ter-lhe-à escrito uma mensagem após a apresentação do artigo "Tangible bits: towards seamless interfaces between people, bits, and atoms" em que reconheceu a importância do projeto *Tangible Bits* para a desmistificação da conotação negativa que a designação "computação ubíqua" possa ter adquirido: «Ubicomp was never just about making "computers" ubiquitous. It was always, like your work, about awakening computation mediation into the environment. The Tabs, Pads, and Boards were simply a way to break out of the mold while still engaging traditional computer scientists (...). I tried to stop using ubiquitous computing because of its misleading implication, but it keeps cropping up again, so I keep returning to it as my umbrella name for lots of work, including Things That Think. Augmented reality was in use for awhile, but again got balkanized in meaning. I have started to talk about Calm Technology as a theme, but it better names a goal than a research project. "Tangible Bits" is very nice, and maybe could serve as an overall umbrella (...). Consultado em <https://www.facebook.com/ishii.mit>

moderna a serviço do capitalismo económico, tendo tocado a um nível essencial o carácter que a produção ocupava até então na existência humana.

Convicto desta modificação profunda, Karl Jaspers (1883 — 1969) desenvolve a sua filosofia em torno da ideia de que a existência numa sociedade de massas tem consequências que se estendem desde o mundo material que habitamos à organização estrutural da sociedade em que a existência toma lugar. Deste ponto de vista, a filosofia existencial de Jaspers, tal como desenvolvida em *Man in the Modern Age* (1931) desenvolve-se no contraste entre dois outros modos distintos de ser: o *Dasein* (utilizando este conceito de um modo distinto daquele de Heidegger, na medida em que aponta o carácter objetual dos artefactos) e o ser como transcendência. Muito embora todas as entidades que possam ser objeto de pensamento tenham o carácter de *Dasein*, designando algo que “está” no mundo, o modo de existência humana desenrola-se de modo completamente diferente, na medida em que “está lá”, mas não coincide absolutamente consigo mesmo, encerrando assim a possibilidade de se relacionar com o “si”. A possibilidade constante de construir o modo de existência define assim a medida da autenticidade da existência humana.

O capitalismo fomenta assim um modo de produção em massa que promove um ambiente material totalmente distinto daquele experienciado nas sociedades pré-modernas, do qual advém a alienação do homem em relação ao mundo e em relação a si mesmo. Por conseguinte, a larga escala de produção e a circulação de mercadoria conduz a que o homem se produza a si mesmo cada vez menos, resultando numa perda de autenticidade. A posição de Jaspers sobre a ameaça constituída pela tecnologia torna-se ambivalente, no sentido em que a sua posição existencialista se faz depender da neutralidade da tecnologia: ao invés de encarar a ubiquidade e profundidade da tecnologia moderna como uma ameaça em si mesma, considera que ultrapassar o demonismo tecnológico requer, em última instância, o reconhecer da neutralidade da tecnologia face às finalidades determinadas pelo homem. A questão é eventualmente deslocada para a responsabilidade humana e para o uso dado à tecnologia.

A filosofia de Martin Heidegger (1889 — 1976) está próxima do seu contemporâneo Jaspers, muito embora a sua preocupação central seja caracterizar a ontologia do “ser”— o seu *Dasein* — no contexto da relação hermenêutica com o real

que o envolve e, especificamente, com os instrumentos ditos manipuláveis (*Zuhandenheit*). Heidegger abre a sua análise sobre a tecnologia justamente formulando a impossibilidade de uma experiência direta do real, fazendo assentar a relação hermenêutica que estabelecemos com o mundo no caráter dos meios tecnológicos que permitem a sua mediação: «Everywhere we remain unfree and chained to technology, whether we passionately affirm or deny it. But we are delivered over to it in the worst possible way when we regard it as something neutral; for this conception of it, to which today we particularly like to do homage, makes us utterly blind to the essence of technology.» (Heidegger, 1977, 4). No que pode ser lido como um comentário a Jaspers, torna-se evidente como ambos representam dois pólos da tradição fenomenológica no seio da filosofia da tecnologia: por um lado, Jaspers coloca-nos diante de uma fenomenologia existencialista que faz do seu cerne a questão de como o homem se pode tornar consciente da sua existência num contexto de mobilização tecnológica; por seu turno, Heidegger desenvolve uma fenomenologia hermenêutica, assim examinado os modos como a realidade é tornada presente para o ser.

Heidegger considera que a tecnologia opera como um modo de desvelar, apropriando o termo grego *alètheuein* — deste modo, define o real não como acessível em si, mas como feito presente no contexto da mediação tecnológica. Em certa consonância com Jaspers, Heidegger considera que o modo de desvelar propriamente moderno é o ponto onde culmina o esquecimento do ser, que tem início na idade clássica com Platão, resultando para Heidegger na dissolução da diferença ontológica entre o “ser” do homem e o “ser” instrumento. Nesse sentido, Heidegger revisita as quatro “causas” da teoria da produção Aristotélica — *causa efficiens* (causa eficiente), *causa materialis* (causa material), *causa formalis* (causa formal) e *causa finalis* (causa final, ou finalidade) — de modo a argumentar que a tecnologia moderna põe em prática um modo de produção distinto daquele implicado na *techne* grega, na medida em que coloca o homem perante uma relação com o real cujo regime de visibilidade é rigorosamente ordenado e se constitui como um modo de revelar que revela a característica fundamental do aparecer como forma de verdade (*aletheia*) (Heidegger, 1977, 12).

Neste contexto, Heidegger considera que a usabilidade do instrumento (*Zeug*) se faz depender da neutralização do seu aparato; o carácter manipulável dos instrumentos, na condição de meios para alguma coisa, faz coincidir o “trazer à frente” com a *causa finalis*, assim inscrevendo os artefactos num modo específico de “ser”, o qual assenta na sua disponibilidade para o uso, geralmente designada como “readiness-to-hand” (*Zuhandenheit*). A natureza do *Zeug* assenta neste ato de recuar da tecnologia para que o seu uso se lhe sobreponha, apenas feito presente quando essa finalidade entra em rutura. Deste modo, o homem moderno apenas pode tomar conhecimento do mundo por via desta ordenação do real, que constitui e é constitutiva do modo de “ser”. Em “The Question Concerning Technology”, Heidegger eventualmente aponta que o grande desafio não reside no aparato tecnológico moderno em si, mas na essência desta ordem do aparecer (*Gestell*) que permanece oculta face ao que é feito disponível. O perigo último da alienação do homem face à experiência original do revelar consiste em que ele próprio seja instrumentalizado como reserva para um processo de mobilização total do real cuja força lhe escapa — ou seja, que o seu modo de ser se torne *Zuhandenheit*:

«The threat to man does not come in the first instance from the potentially lethal machines and apparatus of technology. The actual threat has already affected man in his essence. The rule of Enframing threatens man with the possibility that it could be denied to him to enter into a more original revealing and hence to experience the call of a more primal truth.» (Heidegger, 1977, 28).

Justamente neste ponto, Heidegger partilha do mesmo tipo de nostalgia pré-moderna de Jaspers, na medida em que estas meditações tendem a caracterizar a fenomenologia como a busca por um regresso ao contacto “original” e “autêntico” com a realidade, o que serve de ponto de articulação crítico para o estabelecimento do pensamento pós-fenomenológico nos anos recentes, contexto no qual se destaca o trabalho do americano Don Ihde (1934 — ). Partindo explicitamente da crítica à teoria clássica da tecnologia, Ihde reitera a impossibilidade de uma não-mediação absoluta, já patente em Heidegger, dela reabilitando a ideia de alienação que se revela, com o passar do tempo, consequência direta da conjuntura histórica em que Jaspers e Heidegger desenvolvem o seu pensamento.

Fundamental para a presente discussão acerca do conceito de ubiquidade e para a compreensão da relação com os sistemas de interação tangível, a análise de Ihde acerca da percepção tecnologicamente mediada oferece uma visão abrangente dos diferentes tipos de relação que o homem estabelece com o mundo. Partindo da revisão ao caráter determinístico da mediação tecnológica assim como concebida por Heidegger, Ihde considera que os processos de mediação da percepção ocorrem em configurações distintas, deste modo elencando: *mediation relations* (que inclui *embodiment* e *hermeneutic relations*), *background relations* e *alterity relations*.

No contexto das relações de mediação, a primeira (*embodiment*) assume o fluxo (*eu - tecnologia*) → *mundo* e aproxima-se do cenário ótimo de *readiness-to-hand*, no sentido heideggeriano; neste caso, a relação é pontuada por um determinado grau de transparência, uma vez que a atenção do utilizador é concentrada no mundo mediado através do instrumento e não no instrumento *per se*. Mesmo uma configuração desta ordem não é totalmente determinada no sentido em que a disponibilidade do instrumento se faz depender de um conjunto de fatores contextuais, que incluem o desenho do artefacto (de forma a possibilitar a percepção com a mínima intercepção do medium), o grau de conhecimento para operar o artefacto e a escalabilidade relativamente à percepção não mediada (Ihde, 1979, 6). A segunda configuração é designada de hermenêutica, assumindo o fluxo *eu* → (*tecnologia - mundo*), assim requerendo a leitura do instrumento a fim de possibilitar a adequada compreensão daquilo que é percecionado. O produto do binómio (*tecnologia - mundo*) é geralmente dado sob a forma da representação de um aspeto particular do real, pelo que neste caso o artefacto tecnológico não é totalmente remetido para a periferia da percepção (*ibid.*, 11). As relações de *background* contrastam com os tipos de relações anteriormente discutidos, pois neste caso os instrumentos e sistemas não ocupam um lugar central na percepção, mas atuam sobre o contexto no qual decorre a experiência, operando como um “campo” (*ibid.*, 13). Finalmente, Ihde refere as relações de alteridade, que assumem a estrutura (*eu* → *tecnologia* (- *mundo*)) e nas quais a tecnologia, exibindo traços de equivalência com o comportamento ou morfologia humanas, é percecionada pelo utilizador como “outro”.

Deste ponto de vista, e seguindo o argumento de Ihde, a classificação e consideração de diferentes configurações para a relação homem-artefacto num contexto pós-fenomenológico permite encontrar dois tipos fundamentais de relação: a um nível direto, ou micro, poderemos avançar que existe todo um conjunto de instrumentos ou artefactos quotidianos que informam as perceções, mediando o modo como o real é interpretado. De um ponto de vista indireto, ou macro, a tecnologia opera a mediação de quadros interpretativos que exercem larga influência na tarefa hermenêutica do mundo e estabelecem uma interdependência entre o contexto científico e cultural de determinada época. Quando Weiser refere explicitamente Heidegger e os seus contemporâneos a propósito da computação ubíqua, fá-lo claramente no sentido em que Ihde lê os seus antecessores — ou seja, na defesa do potencial da tecnologia para a mediação da relação hermenêutica entre o homem e o seu ambiente — e não no sentido de advogar a tecnologia como alienante de uma experiência “autêntica” do real.

Poderemos assim dizer que o sistema ubíquo ideal opera essencialmente na periferia da perceção, tirando partido de um conjunto distribuído de dispositivos de *input* e *output* que regulam o fluxo relativamente autónomo de processos. Alguns exemplos mais evidentes da aplicação destes princípios incluem o *ambientROOM* ou o *musicBottles*, os quais visam explorar a ideia de media periféricos por meio visual, tátil e aural. O primeiro questiona como a presença subtil de alguns estímulos na periferia da perceção — o que designam de *ghostly presence* — pode enriquecer a experiência de interação e a sensação de co-presença. O segundo exemplo, um clássico das *media and electronic arts*, propõe uma instalação com um conjunto de garrafas, cuja manipulação permite controlar o fluxo de pistas de som que ressoam no espaço da instalação e são conjugadas com variações de luz ambiente.





Fig. 1  
**musicBottles (1999)**  
 Tangible Media Group /  
 MIT Media Lab

Apesar da centralidade que este conceito assume em alguns dos projetos iniciais do *Tangible Bits*, gradualmente, e à medida que o curso da investigação se aproxima da transição entre *Tangible Bits* e *Radical Atoms*, a aplicação dos princípios da computação ubíqua afasta-se das ideias de Weiser e o grupo concentra os seus esforços em explorar as relações hermenêuticas pré-existentes nos ambientes e objetos quotidianos, visando o desenho de experiências aumentadas que tiram partido dos atributos físicos com os quais estamos familiarizados — ou seja, introduzindo a dimensão computacional como uma prática de extensão do design e do aspeto comunicativo desses objetos e não procurando concentrar o controlo de sistemas distribuídos num dispositivo móvel, como era o caso dos *pads*, *tabs* e *boards* desenvolvidos por Weiser et al: **(UB.1)** «The research themes of augmented reality and ubiquitous computing are also important motivators to the TUI approach, but are marked by important differences. In particular, augmented reality research has generally been directed towards visual augmentations of physical spaces through head-mounted or hand-held displays, where our work focuses on direct physical interaction with objects as elements of TUI interfaces» (Ishii e Ullmer, 1997, 2). Explorar as relações de mediação possibilitadas pelos produtos da investigação do Tangible Media Group requer assim uma conceção de design da experiência de interação e interface que considere mediação e significado para lá das ideias de sujeito e objeto como entidades fixas.

## IV. 2. Superfície

Um segundo aspeto fundamental da proposta de Weiser que perpassa a investigação do Tangible Media Group, consiste na passagem do computador enquanto estação de trabalho para o computador distribuído ao longo de várias superfícies, o que revela ampla consciência do papel central que a ideia de superfície encerra na cultura visual e nos estudos da percepção:

«Pads, in contrast, use a real desk. Spread many electronic pads around on the desk, just as you spread out papers. Have many tasks in front of you, and use the pads as reminders. Go beyond the desk to drawers, shelves, coffee tables. Spread the many parts of the many tasks of the day out in front of you to fit both the task and the reach of your arms and eyes rather than to fit the limitations of glassblowing. Someday pads may even be as small and light as actual paper, but meanwhile they can fulfill many more of paper's functions than can computer screens.» (Weiser, 1991, 6)

Este é um dos aspetos sugeridos pela computação ubíqua que mais pode ter influenciado o trabalho do Tangible Media Group, tendo em consideração a centralidade que o conceito de superfície assume numa larga porção dos seus projetos, servindo de charneira entre os projetos *Tangible Bits* e *Radical Atoms*. Como visto anteriormente, a tabela de frequências de ocorrência dos termos isola dois principais momentos em que o termo é utilizado, a cada um correspondendo um sentido específico. A secção que se segue concerne principalmente o seu primeiro uso — ou seja, a ideia de uma superfície matematicamente codificada que oferece estrutura para a disposição de elementos. Se na primeira secção do presente capítulo são revisitados alguns contributos essenciais para o pensamento sobre a computação ubíqua, o segundo passo requer a consideração da origem e fundamentos das interfaces gráficas a respeito do tratamento das noções de superfície e janela, e acerca do modo como elas perpassam para alguns sistemas de interação tangível.

O computador, enquanto tecnologia, não foi introduzido enquanto o medium que conhecemos hoje, mas sim sob a condição de processador de símbolos — tendo neste sentido sido desenvolvido e financiando por organismos governamentais. A conceção do

computador enquanto medium advém de um conjunto de vozes que, a partir da década de 60, o anteciparam como ferramenta de comunicação e colaboração à distância, incluindo Ted Nelson<sup>12</sup>, Douglas Engelbart<sup>13</sup>, J.C.R. Licklider e Robert S. Taylor<sup>14</sup>. Para concretizar esta visão seria ainda necessário assegurar dois desenvolvimentos fundamentais: o computador pessoal e a World Wide Web, tendo ambos tomado forma nos anos subsequentes, no contexto do Palo Alto Research Center. O computador pessoal significou a passagem do computador a medium, antecipada pela equipa de Alan Kay e pelo seu Dynabook (ou *personal dynamic medium*) apresentado inicialmente como uma ferramenta educacional<sup>15</sup>. Possibilitados os meios de incorporação de diferentes formatos (texto, imagem, som, vídeo), tornou-se evidente a capacidade do computador para a representação e reconfiguração de múltiplos tipos de informação, assim veiculando o mesmo tipo de experiência cultural que antes ocupava livros, jornais, revistas, rádio, filme ou televisão (Bolter e Gromala, 2003, 20). A este ponto, a interface gráfica do Dynabook constitui o aspeto fundamental que permitiu tornar o computador pessoal uma tecnologia de consumo, potencial concretizado posteriormente pelo Macintosh; o seu sistema WIMP (*window, icon, menu e pointer*) utiliza a metáfora da janela como base para a exibição de informação, acedendo ao mesmo tipo de estrutura organizacional da informação sob uma superfície retangular — a folha de papel, a pintura, a tela de cinema — que referem a experiências adquiridas através de media anteriores: «In semiotic terms, the computer interface acts as a code that carries cultural messages in a variety of media. When you use the Internet, everything you access — texts, music, video, navigable spaces — passes through the interface of the browser and then, in turn, the interface of the OS. In cultural communication, a code is rarely simply a neutral transport mechanism; usually it affects the messages transmitted with its help.» (Manovich, 2001, 64). Assim, a entrada do

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<sup>12</sup> Cf., Nelson, T. H. (1987). *Computer lib; dream machines*. Redmond, Wash: Tempus Books of Microsoft Press.

<sup>13</sup> Cf., Engelbart, D e English, W. (1968) A research center for augmenting human intellect, *Conference Proceedings of the 1968 Fall Joint Computer Conference*, 395-410.

<sup>14</sup> Cf., Licklider, J.C.R. e Taylor, R. (1968) The Computer as a Communications Device, *Science and Technology* (76), 21-31.

<sup>15</sup> Cf., Kay, A. (1972) A Personal Computer for Children of All Ages, *Proceedings of the ACM National Conference*. New York: ACM.

computador no conjunto dos media contemporâneos é feita na condição de remediador, canalizando o mesmo tipo de questões culturais que pontuam os media anteriores.

Quando a janela foi escolhida como metáfora para designar os elementos rectangulares da interface que organizam a informação, esta escolha não foi inócua, como aponta Manovich, mas teve um significado vasto e determinante no entendimento cultural do computador. Note-se que o termo escolhido foi *window* e não *frame*, na medida em que o primeiro concentra a atenção para o conteúdo que é tornado visível “através de”, enquanto o segundo desvia a atenção para a interface em si mesma (Bolter e Gromala, 2003, 42). Do ponto de vista elementar das práticas de design de interação, as escolhas não têm um efeito meramente cosmético, mas são decisivas para garantir a consistência e coerência da interface — por outras palavras, assegurar a ilusão<sup>16</sup> de transparência. A eficácia desta ilusão, por seu turno, valida as condições de como o produto final será compreendido pelo utilizador, colocando-o no centro do processo de design. Deste modo, as metáforas que constituem a interface acedem à poderosa metáfora cultural que advém em primeira instância do Renascimento e da perspectiva enquanto dispositivo de representação.

Ao introduzir a janela aberta (*aperta finestra*) como metáfora para a superfície pictórica (*pictura*), Leon Battista Alberti (1404 — 1472) define a pintura como o registo do campo visual tridimensional de um observador posicionado diante desta moldura, o qual ocupa o vértice da pirâmide visual, posição que se traduz simetricamente na posição do observador. Em algumas descrições, o dispositivo inclui um segundo elemento denominado *velo*, um véu semi-transparente que é aplicado sobre a moldura, assim oferecendo uma matriz de referência auxiliar para o posicionamento matemático dos objetos neste campo. Neste sentido, a descrição de Alberti significa: (1) um mecanismo variável de representação que garante o seu realismo, (2) que o lugar de produção e da recepção da representação são determinados, (3) a tensão entre transparência (*finestra*) e opacidade (*velo*) (Friedberg, 2006, 29). Ao assumir a figura humana como ponto cêntrico, o dispositivo da perspectiva assume uma distinção

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<sup>16</sup> A propósito da ideia de interface como ilusão: Tognazzini, B. (1993) “Principles, techniques, and ethics of stage magic and their application to human interface design”, *CHI '93 Proceedings of the INTERACT '93 and CHI '93 Conference on Human Factors in Computing Systems*, 355-362.

fundamental, que é patente no texto seminal de Panofsky, “Perspective as a Symbolic Form” (1924): a metáfora da janela enquanto determinante do realismo da representação e enquanto determinante da experiência espacial daquele que vê. O ponto único e fixo de vantagem do espectador sobre a secção da pirâmide visual significa a translação de um espaço psicológico para um espaço matemático, numa forma de ordenação especificamente moderna:

«Thus the history of perspective may be understood with equal justice as a triumph of the distancing and objectifying sense of the real, and as a triumph of the distance-denying human struggle for control; it is as much a consolidation and systematization of the external world, as an extension of the domain of the self» (Panofsky, 1991, 67 — 68).

Este sentido de distanciamento para objetificação do real e negação desse distanciamento para aceder à necessidade humana de controlo, ressoa indubitavelmente a filosofia de Heidegger e o dispositivo de ordenação do real que é a *Gestell*. No texto intitulado “The Age of the World Picture”, Heidegger posiciona a transição metafísica para a idade moderna no momento em que o mundo se torna imagem. A imagem do mundo (*Bild*) passa a significar a imagem estruturada do mundo (*Gebuild*) que é o produto da capacidade humana de produção que representa e ordena o real, possibilitada pelos meios ilimitados de cálculo, planificação e modelagem do real (Heidegger, 1977, 134 — 135). A representação moderna significa tornar presente no sentido de “readiness-to-hand”; assim, e como já foi referido na secção anterior, falar da *Gestell*, é falar de um dispositivo de “enquadramento” cuja finalidade assenta na disponibilidade e controlabilidade dos objetos, possibilitada pela sua representação e manipulação matemáticas.

Um tal dispositivo de representação tem por consequência a transformação da identidade numa função de um dado posicionamento, assumindo que existe uma estrutura que precede o simbólico; consequentemente, o pensar desta estrutura permite (1) a possibilidade de registar a ausência (zeros e uns), (2) a distinção entre informação e lugar e (3) a extensão potencialmente infinita do tempo e do espaço. O *velo* de Alberti traduz-se na técnica propriamente moderna de uma superfície geometricamente codificada que trespassa os limites da representação artística para se apresentar

enquanto um dispositivo administrativo de importância fulcral uma vez aplicado à cartografia ou à topografia (Siegert, 2015). Séculos depois, a mesma estrutura matricial afigura-se determinante para compreender a origem da computação, bem como da técnica de *bitmapping* utilizada em gráficos digitais. Neste sentido, torna-se evidente como os fundamentos do design de interação incorporaram um conjunto de aspetos determinantes da cultura visual e da modernidade ocidental.

Partindo desta evidência, importa considerar alguns pontos importantes acerca do projeto *Tangible Bits*. Muito embora Ishii refira frequente — e hiperbolicamente —, a ideia de uma “guerra contra o império dos pixéis”<sup>17</sup>, algumas das primeiras propostas assentam paradoxalmente no prolongamento da interface para lá do ecrã de computador, o que depende mais ou menos invariavelmente da extensão de uma mesma estrutura matricial sobre outras superfícies, de modo a permitir o controlo e visualização dos processos de interação: **(SP.66)** «More recent augmented surfaces work adds the notion of a spatially continuous connection between the screens of portable computers and nearby tablets and wall surfaces» (Patten et al., 2001, 5). Este é o princípio base de sistemas de Table Top Tangibles como o *Sensetable*, os quais dependem do mapeamento de uma superfície de interação sobre a qual são dispostos diversos *tokens* (objetos físicos que representam objetos digitais) e *dials* (objetos físicos que representam ações)<sup>18</sup>; um dispositivo de *scanning* é empregue para detectar qualquer diferencial nas posições dos objetos entre dois mapeamentos consecutivos, oferecendo assim um *output* gráfico que é projetado sobre a mesma superfície ou sobre uma superfície contígua, conforme os casos; neste caso, a mínima latência é determinante para assegurar a consistência da interface e a sensação de interação (Patten et al., 2001). Tirando partido desta lógica, a mesma tecnologia foi diversas vezes aplicada na prototipagem de sistemas auxiliares de planeamento urbano e topográfico, como são o *Urp*, ainda sob a categoria dos Table Top Tangibles, ou o *PSyBench*, o *Actuated Workbench* e o *PICO*, dentro da categoria de Actuated Table Top Tangibles.

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<sup>17</sup> Cf. McGoogan, C. (15 de Outubro, 2015) The MIT Media Lab is waging war on pixels, *Wired*. Consultado em: <http://www.wired.co.uk/article/hiroshi-ishii-wired-2015>.

<sup>18</sup> O tipo de *dials* utilizado no *Sensetable* é bastante semelhante ao acessório designado Surface Dial, introduzido em 2016 pela Microsoft para o seu modelo Surface Studio.

Estes sistemas têm em comum trabalharem a superfície enquanto estrutura que permite determinar um sistema de posições para mapear os objetos sobre ela dispostos, sendo a posição ocupada por cada objeto determinante para agenciar a sua função. Os sistemas do tipo Table Top Tangibles empregam tecnologias de mapeamento para determinar as posições em tempo real e permitir a sua correspondência para o modelo digital. Por seu turno, o desenvolvimento dos objetos elencados sob a categoria Deformable Tangibles, sugere um afastamento deste modelo rígido de correspondências para um tratamento distinto do termo superfície. Esta afigura-se menos como estrutura para a disposição e mapeamento dos objetos, passando a apresentar-se como agente ativo nos processos de interação. A superfície abandona o seu estado inerte/passivo e adquire capacidade de *input* e *output* dinâmicos, com capacidade atuante e expressiva em tempo real.

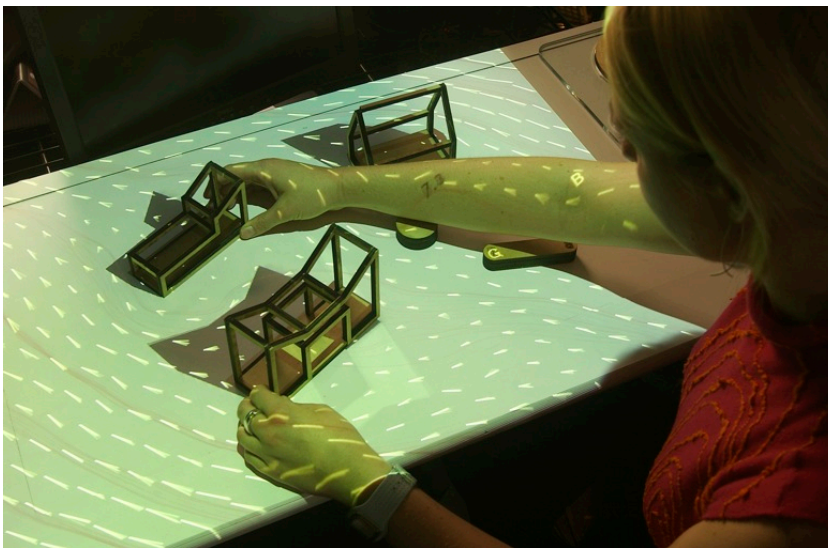


Fig. 2  
*Urp* (2000)  
Tangible Media Group /  
MIT Media Lab

O *Illuminating Clay* e o *Sandscape*, já dentro da categoria de Deformable Tangibles, estabelecem a charneira para a noção de maleabilidade que é própria ao discurso dos *Radical Atoms*, no modo como procedem à substituição do sistema de correspondência de *tokens* e *dials* por um material cuja maleabilidade permita a manipulação direta da superfície como auxiliar ao processo de simulação em tempo real: (SP. 149) «While tracked physical models interfaced with a computer are not a novelty, we believe that Illuminating Clay and SandScape offer a new contribution, by

using the continuous surface geometry of the model itself to act as the input/output mechanism.» (Ishii et al., 2004, 295). Os Deformable Tangibles abrem o espaço de design que é posteriormente explorado pelos Dynamic Shape Displays, uma das tipologias com maior destaque no contexto do *Radical Atoms*<sup>19</sup>. O seu denominador comum é a utilização de matrizes mecânicas de pinos acoplados a sistemas sensoriais que permitem a representação de informação digital e atuação direta sobre estes *displays*, criando uma experiência de *embodiment* com a interface.

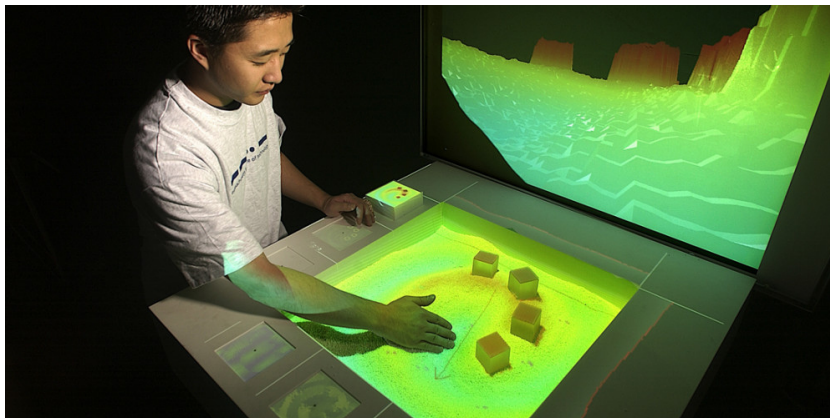


Fig. 3  
**Sandscape (1999)**  
Tangible Media Group /  
MIT Media Lab

Os Dynamic Shape Displays constituem aproximações a este horizonte, das quais resultam ferramentas auxiliares capazes de integrar, na medida dos constrangimentos atuais, o grau de deformação necessário para garantir a sua utilidade no espaço do atelier: **(SP.450)** «For example, CAD applications are split into solid modelers, which involve boolean and parametric operations on “solid” parts while surface modelers usually render the model only has a surface to be manipulated and deformed as a mesh» (Nakagaki et al., 2016, 5). Dentro desta tipologia, destacam-se as aplicações *inFORM*, *Transformable* e *Materiable*, as quais trabalham com particular ênfase as relações entre o ótico, o háptico e a *gestalt* consequentes do materializar da relação entre superfície e profundidade com base no seu denominador comum: a

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<sup>19</sup> Estes objetos foram exibidos em contextos particularmente diferentes, que incluem o Cooper Hewitt, Smithsonian Design Museum (12.2014 - 05.2015, New York), o Lexus Design Amazing 2014 (Milano) e, claro, a Ars Electronica 2016. Importa assim sublinhar como exemplos são ilustrativos das *Media and Electronic Arts* como laboratório para experimentação, a um ponto em que os standards de usabilidade determinam em larga escala a configuração das interfaces com que nos relacionamos numa base quotidiana.



estrutura matricial que possibilita a organização do espaço de representação. Com estas aplicações, o grupo pretende empregar uma amplitude de *affordances* e propriedades materiais perceptíveis haptica e visualmente, enriquecendo o tipo de comunicação possibilitada pelos métodos atuais de modelagem em gráficos 3D.

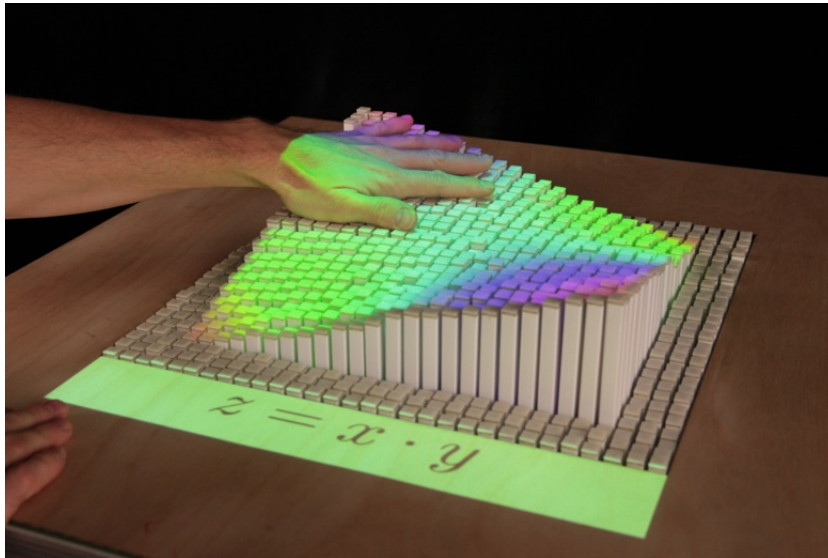


Fig. 4  
**inFORM (2013)**  
Tangible Media Group /  
MIT Media Lab

#### IV. 3. Forma

O tratamento do termo “forma” segue o espaço aberto pelos Deformable Table Top Tangibles e aponta os fundamentos da visão *Radical Atoms*. As secções anteriores demonstram como a visão *Tangible Bits* dependeu de um conjunto de dispositivos que expande a superfície de interação para lá do *display* gráfico do computador, permitindo que a interface ocupe e aumente o ambiente experienciado pelo utilizador, enriquecendo a experiência perceptiva pelo estímulo simultâneo das dimensões ótica e háptica. Para concretizar esta visão, os investigadores do Tangible Media Group procuraram explorar a expressão material dos artefactos quotidianos, a eles acoplando informação e processos digitais de modo a que estes possam ser fisicamente manipulados no contexto desta interface expandida. Contudo, esta técnica é limitada pelo desenvolvimento de um léxico de associações possíveis entre objetos físicos e elementos digitais, que se mantém aquém da plasticidade dos gráficos digitais, os quais podem ser facilmente manipulados para modificar a sua forma, posição e propriedades em tempo real (Ishii et al., 2012, 40). Tal evidência motiva o grupo a aplicar novas técnicas e materiais no desenho de

interfaces que exibam elevado potencial de expressão formal para comunicação das suas *affordances* e *feedback*, que são designadas de *Material User Interfaces* (MUI) ou *Organic User Interfaces* (OUI): **(FO.42)** «Malleable and organic user interfaces have the potential to enable radically new forms of interactions and expressiveness through flexible, free-form and computationally controlled shapes and displays.» (Follmer et al., 2012, 1).

O projeto *Radical Atoms* é assim apresentado como um futuro possível para a interação humano-computador que perspetiva uma nova classe de materiais de ponta com elevado grau de reconfiguração plástica, assim procurando soluções que ultrapassem o substancialismo da relação entre os domínios físico e digital. Este horizonte hipotético dependeria assim de materiais capazes de cumprir três requerimentos: 1) transformar, na medida em que a interface deve permitir *input* direto por via de manipulação física e gestual; 2) conformar a interação a um conjunto de *constraints* decorrentes da programação das propriedades físicas de cada material particular e 3) informar o utilizador das suas capacidades transformacionais.

A maleabilidade e a capacidade de reconfiguração desta classe de materiais leva a um outro entendimento dos processos de design, nos quais o aspeto físico e o digital passam a funcionar como um mesmo processo de conferir forma, ou informar, o real. Tradicionalmente, a disciplina de design advoga a imposição de uma ideia sobre um material, o que garante a consistência espacial e temporal do produto final; ao considerar que a forma e ideia se opõem, o senso comum acede e simplifica a dicotomia grega que influencia a conceção da cultura ocidental sobre a natureza do real. Contudo, Flusser (1999) relembra que o entendimento comum da oposição entre imaterial e material advém da tradução do termo Grego *hyle* para o Latim *materia*, sublinhando que o termo original não visava designar matéria, no sentido de matéria-prima, mas sim oferecer o termo oposto a *morphe* (forma). Neste sentido, *hyle* expressa a natureza amorfa, mutável e ilusória dos fenómenos, relativamente ao caráter eterno e imutável das formas (Flusser, 1999, 22), pelo que a oposição comum entre imaterial e material, sob a qual assenta a dicotomia entre físico e digital, perde o seu sentido na medida em que ambos são parte constituinte do gesto do designer como prática constitutiva da condição informe do real — informe pela sua mutabilidade e multiplicidade.

Do ponto de vista da cultura visual, o modelo matemático de organização do espaço do Renascimento, com o seu dispositivo da perspetiva, determina um modo de representação em que cada ente pode apenas e tão somente ocupar uma única posição, assim acedendo à ideia rígida de contentor e conteúdo, naquele que é um modelo caracteristicamente moderno. Porém, com Cézanne e os impressionistas, levado ao extremo por Picasso e pelos cubistas, ocorre um momento fraturante na lógica da representação pictórica em que a sua veracidade, que outrora fora feita depender da adequação a este modelo matemático, passa agora a registar o carácter mutável do real — o informe: «One can therefore say of this sort of painting that, moving between content and container, between material and form, between the material and the formal aspect of phenomena, it approaches that which is referred to, incorrectly, as the “immaterial”» (Flusser, 1999, 27). Assim, a prática de design que anteriormente consistia em conferir ordem formal (um *nomos*) ao real dado por garantido, encontra no contemporâneo o desafio de conceber a produção de um infinito de figuras que, na vertigem da sua propagação tecnológica, produzem e sobrepõem instâncias do real em mutação. No contexto do objeto da presente dissertação, esta mutabilidade e multiplicidade são alcançadas pelos produtos do projeto *Radical Atoms*.

Para compreensão das características fundamentais destes objetos, é convocada a noção de “compósitos computacionais”, proposta por Vallgård (2014). Os compósitos computacionais sugerem a reconfiguração das práticas de design, na medida em que posicionam a forma espacial e temporal como um mesmo processo de informar o real, respondendo à sua natureza mutável e informe:

«Computational composites are the material from which the two forms come to be. Designing with them is thus designing the physical and temporal form in the same process, and through that formation encourage certain interaction gestalts. Similar to how the cabinetmaker gradually gives form to the wood and the interaction gestalt in unison.» (Vallgård, 2014, 9)

Deste modo, o tipo de objetos que encontramos no contexto dos Programmable Materials e Kinetic Materials, é o produto da exploração de novas linguagens expressivas que se adequem e apliquem as propriedades únicas dos compósitos materiais em interfaces com elevado grau de usabilidade: **(FO.128)** «Our belief is that

shape-changing interfaces will become increasingly available in the future, and this work tries to push towards creating a vocabulary and design space for more general-purpose interaction for shape displays, including rendering of both content and UI elements.» (Follmer et al, 2013, 2).

As práticas em design de interação para compósitos computacionais deve assim mediar a (1) forma física, a (2) *gestalt* de interação e a (3) forma temporal. Deste conjunto, a forma física designa a presença tridimensional do artefacto no ambiente, possibilitando a percepção das suas propriedades físicas pelo aparelho sensorio humano. A *gestalt* de interação determina o conjunto de ações possíveis em relação ao artefacto em determinado ambiente, conjunto esse que é comunicado ao utilizador através de sugestões visuais, hápticas ou aurais, as quais não são necessariamente inequívocas (o utilizador pode performar outras ações que não aquelas pretendidas pelo designer). Deste modo, a expressão estética dos artefactos em uso define a funcionalidade na mesma medida em que a funcionalidade define a expressão estética — o que Hallnäs e Redström definem de *function-expression circle*<sup>20</sup> — e menos no sentido de *form follows function*. Por último, a forma temporal é o fator que diferencia os compósitos computacionais, na medida em que permitem o controlo matemático da dimensão temporal em que se desenrolam a forma física e a *gestalt* de interação, de um modo que não é possível com outros materiais (Vallgård, 2014, 7).



Fig. 5  
**PneUI (2013)**  
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<sup>20</sup> Cf., Hallnäs, L. and Redström, J. (2006) *Interaction Design: Foundations, Experiments*. Borås: The Interactive Institute and The Swedish School of Textiles University College of Borås.

A mediação destas dimensões no processo de design permite projetar interfaces que uniformizam percepção sensorial e informacional: **(FO.779)** «We envision a future for shape changing interfaces where rendered materials can be recognized by their perceived material properties, directly manipulated and used in applications to enable rich new experiences with digital information» (Nakagaki et al., 2016, 8), o que é especialmente patente nos Programmable Materials e nos Kinetic Materials. No primeiro caso, podemos encontrar uma vasta exploração de técnicas e materiais que incluem *particle jamming* por via pneumática ou hidráulica, ligas com capacidade de memorizar forma, *displays* de pinos, películas bio-híbridas, elastómeros variados, papel, metal em folha, fio ou líquido, tecidos e tintas condutoras. A título de exemplo, no *PneUI*, a aplicação de vários destes materiais numa arquitetura estratificada possibilita a obtenção de uma interface maleável e capaz de detetar atuação gestual e deformação sobre a superfície. Noutro exemplo, o *bioLogic*<sup>21</sup> propõe uma interface de inspiração orgânica, em analogia a uma segunda pele, com aplicação no desenho de vestuário desportivo com elevado grau de adaptabilidade a fatores contextuais: a sua estrutura “celular” reage à temperatura e movimento corporais, de modo a garantir um mecanismo de auto-regulação.



Fig. 6  
**bioLogic (2015)**  
Tangible Media Group /  
MIT Media Lab

<sup>21</sup> O bioLogic foi desenvolvido conjuntamente com o Departamento de Engenharia Química do MIT, o Royal College of Art e a marca New Balance. Trata-se de uma das aplicações de maior destaque no contexto do projeto *Radical Atoms*, tendo sido distinguido nos A' Design Awards 2016 nas categorias de Textile, Fabric, Textures, Patterns and Cloth Design; Wearable Technologies Design; e por último, Fashion, Apparel and Garment Design.

Como visto anteriormente, existem duas principais formas de exploração de formas dinâmicas: o desenvolvimento de interfaces maleáveis, através dos Programmable Materials descritos acima, e o desenvolvimento de kits modulares que permitem a programação de funções com base na manipulação e combinação de pequenos *robots*, os quais são designados Kinetic Materials: **(FO.588)** «Currently, two approaches for creating dynamic shapes dominate: using shape-changing interfaces, like shape displays, or combining multiple modular elements, like small robots» (Schoessler, 2015, 1). No caso desta segunda tipologia, é explorada diretamente a programabilidade dos compósitos computacionais, que assenta num conjunto de propriedades específicas: (1) reversibilidade, como a modificação recursiva da sua capacidade expressiva entre dois ou mais estados; (2) acumulação, significando que um estado expressivo pode gradualmente tornar-se mais explícito que outros. A reversibilidade e acumulação oferecem duas formas de controlar a temporalidade em termos de expressão material, sendo considerados *loops* de um ponto de vista de programação. Seguem-se a (3) causalidade computacional, que designa a propriedade que liga causa-evento e efeito-evento, no sentido de funções *if-then-else*; e a (4) conectividade, permitindo que duas partes não contíguas possam reagir mutuamente, assim como se estivessem fisicamente ligadas (Vallgård, 2014, 12). Da exploração destas propriedades emergem aplicações como o Topobo, o qual constitui um kit modular que emprega memória cinética para demonstrar as propriedades descritas acima e deste modo estimular o *storytelling* e a familiaridade com os fundamentos de programação em contexto educacional.

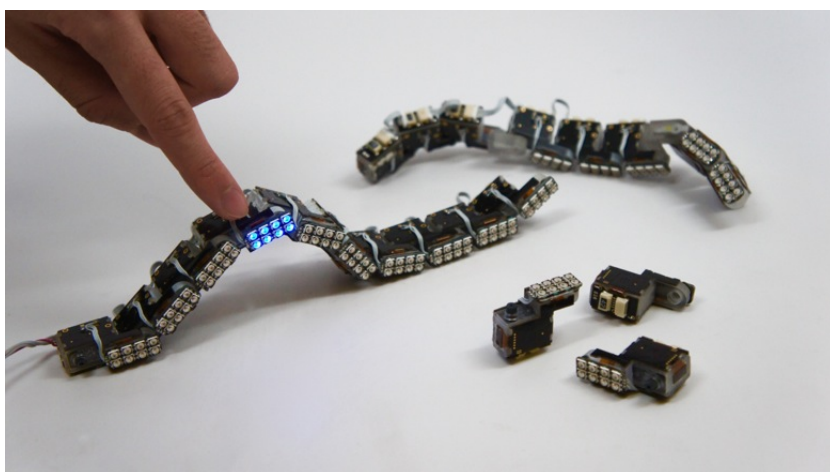


Fig. 7  
**ChainFORM (2016)**  
Tangible Media Group /  
MIT Media Lab

O *ChainFORM* oferece um outro exemplo mais avançando de como a modularidade pode ser aplicada para a programação de um vasto conjunto de aplicações que tiram partido das capacidades I/O de cada um dos pequenos *robots*; cada módulo tem sensibilidade ao toque, deteção angular, *output* visual e atuação motora, possibilitados por um servomotor e uma placa de circuitos flexível com um microcontrolador.

Os produtos do *Radical Atoms*, como aqueles enumerados acima, levantam algumas questões sobre a relação hermenêutica e cognitiva que é possível estabelecer com os múltiplos estados de expressão material destes objetos. A este propósito, o designer Ezio Manzini (1989) considera que os desenvolvimentos na ciência dos materiais levaram a que o designer convoque cada material menos em termos das suas propriedades — o que é este material? — e mais em termos das suas potenciais aplicações e performance — o que faz este material? Deste modo, Bergström et al. (2014) argumentam, com base na proposta de Manzini, que dadas as propriedades temporais e programáveis da expressão dos compósitos computacionais, estes destacam o seu carácter enquanto *becoming materials*. Colocam então uma terceira questão — no que se pode tornar este material? — referenciando explicitamente as conceções pós-estruturalistas de performatividade nas ciências sociais. Naturalmente, qualquer material, inclusivamente os compósitos computacionais, podem ser definidos em termos de “ser”, “fazer” e “tornar”, muito embora tais termos não sejam suficientes para exprimir o potencial transiente destes materiais e as constantes transformações que realizam com base na mediação com fatores contextuais (Bergström et al., 2014, 2).

A recolha e localização dos termos “ubíquo”, “superfície” e “forma”, conforme detalhadas nos Capítulos III e IV, permitiram estabelecer o arco entre o trabalho do Tangible Media Group e os estudos dos media. A primeira secção do capítulo que agora se encerra, dedicada ao termo “ubíquo”, partiu da fenomenologia existencialista de Karl Jaspers e da fenomenologia hermenêutica de Martin Heidegger, de modo a evidenciar o denominador comum entre a proposta da computação ubíqua e a interação tangível. Partindo destes autores, foi abordada a teoria pós-fenomenológica de Don Ihde, junto da qual foram identificadas as questões estruturantes da teoria da mediação tecnológica

enquanto o enquadramento para a análise das relações que a tecnologia desempenha em relação à existência humana e em sociedade.

Foi com base neste enquadramento que a segunda secção se propôs a localizar as referências ao termo “superfície”. Como visto anteriormente, um dos traços característicos do projeto *Tangible Bits* é o desenvolvimento de sistemas que recorrem à disposição e monitorização de objetos discretos sobre superfícies matematicamente codificadas, de modo a assegurar um sistema de correspondências entre as ações tomadas sobre esses objetos e as ações dos seus análogos digitais. Assim, foi criado um paralelo entre estes sistemas de interação tangível e a perspetiva como dispositivo de ordenação do real, sugerindo que, no contexto da visão *Tangible Bits*, o estado de cada objeto é definido em função na sua posição no sistema, assim comunicado com a ideia heideggeriana de *Gestell*. Esta sugestão corresponde à primeira conotação dada ao termo “superfície”, conforme detalhado anteriormente.

Por outro lado, a segunda conotação dada ao termo “superfície” respeita à superfície como área de atuação para *input* e *output*, remetendo já para o terceiro termo tratado: “forma”. Desta dupla conotação dada ao termo “superfície” é possível compreender a articulação entre os projetos *Tangible Bits* e *Radical Atoms* — ou seja, a passagem de uma superfície que funciona como estrutura, para uma superfície como agente. A terceira secção do capítulo anterior partiu de algumas considerações de base sobre as ideias de forma e informe, imaterial e material, para detalhar a natureza característica dos objetos produzidos sob o projeto *Radical Atoms*. Ao convocar a ideia de *becoming materials*, é ainda sublinhado o caráter processual e coletivo destes objetos, o qual adquire grande centralidade ao longo da discussão que ocupa o capítulo que se segue.



## V. SISTEMAS DE INTERAÇÃO TANGÍVEL E PROCESSOS DE MEDIAÇÃO TECNOLÓGICA: DISCUSSÃO SOBRE AGÊNCIA, SIGNIFICAÇÃO E COGNIÇÃO

Posto isto, o último capítulo da dissertação propõe um conjunto de pontos de discussão sobre o trabalho do Tangible Media Group, propostos como complementares à leitura do tema da edição de 2016 do Festival Ars Electronica, *Radical Atoms: The Alchemists of Our Time*. Importa sublinhar que esta discussão, assim como o âmbito geral da dissertação, pretende tomar o trabalho do MIT Tangible Media Group enquanto um objeto que é apresentado num espaço específico, o Festival Ars Electronica, o que motiva a releitura deste objeto no contexto específico dos estudos dos media, dada a linha programática do Festival.

O conjunto de ideias sintetizado no capítulo anterior estabelece o espaço para a discussão da visão *Radical Atoms* em função das suas possibilidades de mediação da experiência quotidiana. O articular dos dois projetos do Tangible Media Group no contexto dos estudos dos media, relevou um conjunto de pontos de discussão sobre como se constituem os agentes, que significação e que experiência cognitiva são possíveis na relação de uso com estes objetos específicos. A análise do *corpus* permitiu compreender como estes sistemas de interação tangível assentaram inicialmente na relação necessária entre estrutura e agentes “passivos”, sendo posteriormente reconfigurados no sentido da dissolução destas distinções, em concordância com a visão *Radical Atoms*. Esta modificação enfatiza o carácter das interfaces enquanto processos, assemblagens e performances “ativas”, que participam e co-constituem a experiência quotidiana, ativando fluxos de significação de modo distinto relativamente a outras propostas sobre a computação ubíqua.

Deste modo, a visão *Radical Atoms* reconfigura a relação entre elementos no cenário de interação humano-computador, ao (1) confluir num mesmo objeto o conjunto de sistemas e dispositivos necessários ao *input*, *output* e processamento de informação, os quais são, por regra, apresentados separadamente ao utilizador; (2) ao desenhar sistemas com elevada capacidade de atuação direta e expressão material dinâmica, os

quais não encontram correspondência nos esquemas para a relação *eu — tecnologia — mundo* revisitados até este ponto da dissertação; (3) ao confluir propriedades materiais e processos digitais, sugerindo a reavaliação das metáforas de interação utilizadas pelas interfaces convencionais; (4) ao possibilitar um modo distinto de entendimento e envolvimento com a informação e com o caráter material dos objetos quotidianos. Esta reconfiguração motiva a discussão acerca da agência, significação e cognição implicados nestes sistemas de interação tangível.

A visão *Radical Atoms* sugere a reavaliação das fronteiras convencionais entre organismos, superfícies e interfaces, significando que qualquer operação cognitiva emerge da articulação e coordenação dinâmicas entre agentes e estruturas, fatores internos e externos, aspetos mentais e físicos. Significa isto que os postulados da fenomenologia existencialista e da fenomenologia hermenêutica se revelam inconsistentes com esta fluidez contemporânea entre sujeito e objeto. Se por um lado a fenomenologia existencialista considera que a existência humana é concebida sobre um modo específico e historicizado de mediação com o real, a fenomenologia hermenêutica considera que a experiência advém da mútua intersecção entre a micro-percepção decorrente da interação com determinados artefactos e do âmbito macro em que este exercício hermenêutico toma lugar. Deste modo, a relação entre ação e existência, do ponto de vista do primeiro, é simétrica àquela entre percepção e experiência, do ponto de vista do segundo.

De modo a ultrapassar as dicotomias radicais entre sujeito e objeto, humano e não-humano afetas ao pensamento moderno, recorre-se ao trabalho de Bruno Latour, o qual se debruça precisamente sobre as formas como os atores são continuamente produzidos quando colocados em relação com outros atores. A teoria ator-rede (orig., *actor-network theory*) assenta assim na noção fundamental de que a ontologia dos atores (ou atantes, apropriando diretamente o termo *actant*) depende necessariamente do conjunto de relações que estabelecem entre si a cada momento, em termos de igualdade:

«This point will help to not confuse ANT with one of the many polemical movements that have appealed to the ‘concreteness’ of the human individual with its meaningful, interacting, and intentional action against the cold, anonymous, and abstract effects of the ‘determination by social

structures’, or that has ignored the meaningful lived world of individual humans for a ‘cold anonymous technical manipulation’ by matter. Most often inspired by phenomenology, these reform movements have inherited all its defects: they are unable to imagine a metaphysics in which there would be other real agencies than those with intentional humans, or worse, they oppose human action with the mere ‘material effect’ of natural objects which, as they say, have ‘no agency’ but only ‘behavior’.» (Latour, 2005, 61)

A proposta depende assim de uma concepção de ator cuja agência transcende a singularidade da intencionalidade humana face ao mundo em seu redor, dado como realidade estável. A cisão entre o modo de existência humano (o sujeito, o social, a cultura) e o modo de existência não-humano (o natural, o objetual, o material), perde o seu sentido no momento contemporâneo; conseqüentemente, a produção de conhecimento não pode mais assentar na distinção do que é o modo de ser propriamente humano em oposição ao não-humano. Neste sentido, Latour procura apreender a complexidade dos processos de mediação com base em quatro aspetos: (1) a translação (orig., *translation*) de um programa de ação entre utilizador e artefacto, no sentido da mediação entre o conjunto de ações tomadas e das funções oferecidas pelo objeto, (2) a composição (orig., *composition*) que determina o carácter necessariamente colectivo do programa de ação, uma vez que é necessária a coordenação de um conjunto de elementos para que ocorra a translação, a (3) caixa-negra reversível (orig., *reversible black-boxing*), dado que considerar a mediação como dissolução da dicotomia entre humano e não-humano implica a opacidade do processo de produção conjunta dos atores e artefactos enquanto assemblagem, e por fim a (4) delegação e guiões (orig., *delegation* e *scripts*) na medida em que a inscrição de um programa de ação num artefacto implica o delegar de uma tarefa que pode respeitar ao seu ator, espaço e/ou tempo (Latour, 1994). Justamente porque a inscrição do programa de ação pelo designer é sujeita ao carácter coletivo e temporal do processo, ele não determina necessariamente a ação tomada pelo utilizador, podendo subscrever ou não as ações sugeridas pelo design do artefacto. As quatro dimensões enumeradas determinam assim, no contexto da teoria de Latour, a reconsideração da noção de agência de modo consonante com o que

é o âmbito do projeto *Radical Atoms*, abrindo assim o espaço para discutir a natureza semiótica dos estados de expressão dinâmicos e as suas implicações cognitivas.

Latour oferece vários exemplos, sendo um deles o da lombá na estrada: neste caso, existe um programa de ação “reduzir a velocidade” que é mediado entre o polícia sinaleiro, os condutores, a estrada, as condições climatéricas...; aqui, a introdução de uma lombá no local acede à delegação implícita do programa de ação do polícia sinaleiro sobre um outro ator, a lombá. Este exemplo de ato de delegação é especialmente interessante em termos semióticos, pois o gesto que o polícia executa para comunicar o seu programa de ação é bastante distinto do modo como a lombá comunica o mesmo programa: «In this case, we leave the negotiable representational realm and enter into the territory of brute yet meaningful material relations. In this real, the medium is the message, and to ignore or misinterpret the sign has immediate and direct physical consequences.» (Malafouris, 2013, 124). Este signo inerentemente material, é designado por Lambros Malafouris de “enativo”, na medida em que não acede ao carácter negociável e arbitrário do signo linguístico.

Para a caracterização do signo enativo, importa considerar a distinção entre a função designativa ou denotativa e a função expressiva dos signos. Na base dos estudos da semiologia, o estruturalismo de Ferdinand de Saussure (1857 — 1913) assenta na arbitrariedade do signo linguístico, na medida em que a relação entre significado e significante não é motivada por nenhum aspeto do real, deste modo acedendo a uma lógica essencialmente nominalista. Por seu turno, a proposta do seu contemporâneo Charles Peirce (1839 — 1914) permite contrabalançar a tendência nominalista, desenhando um esquema compreensivo sobre a expressão material, distinguindo entre ícones, índices e símbolos, sendo: (1) ícones, signos motivados por uma relação de semelhança visual; (2) índices, signos motivados por uma relação de contiguidade espaço-temporal; e (3) símbolos, signos motivados arbitrariamente, no sentido saussuriano. Muito embora Peirce abra o precedente para o reconhecimento dos diferentes graus mediante os quais as instâncias do real podem motivar os processos semióticos, o seu esquema continua a não oferecer uma explicação sobre como os signos se podem constituir e ganhar força mediante um real em permanente mutação. Segundo Malafouris, essa potência advém do carácter enativo do signo material que, ao

contrário do signo linguístico, não tem uma função eminentemente comunicativa ou representacional. Ao invés de se fazer depender do nominalismo inerente à lógica da representação como o “estar em lugar de”, sendo esse lugar ocupado por um particular e nenhum outro<sup>22</sup>, o signo enativo é o resultado da integração processual entre os domínios material e conceptual, integração da qual advém a sua força expressiva:

«The linguistic sign, being denotative, operates on the principle of equation. The word, by convention equates to a definition. However, in the case of the material sign such an equivalency is rarely the case. (...) The predicates that have to be brought to bear on these questions, and the inferential processes that such a sign evokes, are far more complicated than those we see in the case of words. The questions evoked may include questions of being and substance, questions of what is and is not, questions of quantity and quality, questions of relation and becoming, questions of place and time, questions of position and state, and questions of potentiality and actuality.» (Malafouris, 2013, 97)

Considerando comparativamente os objetos inseridos na visão *Tangible Bits* e na visão *Radical Atoms*, e conforme esboçado anteriormente, os primeiros acedem a uma lógica nominalista no modo como os seus sistemas motivam a correspondência entre *tokens* e *dials*, objetos e processos digitais. Estas relações, muito embora não sejam totalmente arbitrárias, continuam sendo motivadas por relações de contiguidade ou similaridade com artefactos físicos quotidianos, assim participando do que é a lógica do signo linguístico. Por seu turno, ao integrar o aspeto material e conceptual no desenho de artefactos com capacidade expressiva mutável, os produtos da visão *Radical Atoms* posicionam-se definitivamente no que é o domínio do signo enativo.

A capacidade expressiva mutável do signo enativo é identificada no contexto do Tangible Media Group enquanto *affordances* dinâmicas. A introdução do conceito *affordances* deve-se a James Gibson (1904 — 1979) no texto “The Theory of Affordances” (original de 1977, doravante referenciado na sua reprodução de 1986), designando-as como a capacidade de adequação de cada ser a um ambiente particular.

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<sup>22</sup> O carácter nominalista da representação é abordado com maior detalhe na segunda secção do Capítulo III, com respeito ao contributo de Erwin Panofsky, *Perspective as Symbolic Form*.

Neste trabalho, Gibson cruza ecologia e psicologia para comparar as *affordances* com o que designa de “nichos do ambiente” (orig., *niches of the environment*); cada nicho oferece ao animal uma conjuntura de fatores específica, e cada animal participa dessa mesma conjuntura, de tal forma que cada nicho implica um tipo específico de animal, e cada animal um tipo específico de nicho — estamos portanto diante de uma relação de mediação que viabiliza a “simbiose” entre um ser e um conjunto de fatores, relação essa que aponta em dois sentidos: o sentido do ambiente e o sentido do observador. A informação sobre a *affordance* respeita tanto à utilização do ambiente, como às capacidades do observador (Gibson, 1986, 141).

Por seu turno, Donald Norman (1935 —) considera as *affordances* enquanto as propriedades perçecionadas e efectivas que sugerem a medida de possibilidade em que um artefacto pode ser utilizado; ao contrário de Gibson, para quem as *affordances* são determinadas (a informação é transmitida ou não) e determinam (a relação de adequação ocorre ou não), ignorando assim o aspeto pragmático da comunicação, para Norman o contexto, conhecimento, experiência e cultura do utilizador constituem variáveis relevantes para a percepção das *affordances* sugeridas. Os princípios fundamentais para o desenho de artefactos que comuniquem os seus usos de modo eficiente depende assim da solidez do seu modelo conceptual e da sua visibilidade, de modo que permita facilmente antever as ações a tomar e os respetivos resultados. O modelo conceptual inscrito pelo designer sobre o artefacto deve ser comunicado de forma clara e consistente pela imagem do sistema e essa imagem deve refletir e ser refletida no modelo mental do utilizador. Esta mediação de horizontes que Norman descreve encontra um paralelo no modelo de mediação tecnológica de Latour detalhado anteriormente, estando o modelo conceptual e o programa de ação em posições sensivelmente simétricas.

Já no caso particular dos compósitos materiais e da sua natureza inerentemente mutável, o modelo conceptual do designer ou programa de ação, conforme descritos anteriormente, não visa apenas comunicar o leque de ações que podem ser levadas a cabo com um determinado artefacto e o resultado possível de cada ação, mas deve também considerar o aspeto temporal, sequencial e contextual da interação. Consequentemente, o modelo conceptual do designer deve incorporar um guião —

jogando aqui com o termo *script* empregue por Latour — no qual são programadas as relações de I/O e as interações significantes que o artefacto estabelece quando colocado em relação com outros atores numa mesma assemblagem, segundo as propriedades programáveis apontadas por Vallgård (2014). A apropriação do termo *scripting* não é fortuita, na medida em que remete para o conceito de *script* em computação, o qual designa uma linguagem de programação cujo ficheiro é geralmente interpretado, em vez de compilado para a sua execução. Definindo sumariamente o termo, pode-se dizer que o processo de compilação assegura a tradução de uma linguagem de programação escrita para a linguagem necessária ao processador e sistema operacional, ao ponto que o *script* introduz um conjunto de comandos que são interpretados por um segundo programa. Em desenvolvimento multimédia, *scripting* designa ainda as sequências de ação que podem ser programadas segundo uma lógica condicional de modo a automatizar processos do programa com base nas condições correntes. Deste modo, as práticas de design com aplicação desta classe de materiais têm a particularidade de incorporarem modelos conceptuais (programas) que atuam sobre a materialidade do artefacto, de forma a oferecerem um guião que é interpretado ao longo da experiência de interação.

Tais propriedades dos compósitos materiais oferecem um espaço de design profícuo ao reconhecimento da agência dos artefactos, o que significa conferir-lhes um papel simétrico nos processos de co-constituição dos atores em rede. Isto significa a consideração dos artefactos como atores que inscrevem as suas dinâmicas e significações próprias no contínuo bio-evolucionário, na medida em que participam nas assemblagens e ecologias cognitivas. Em termos latos, a designação interface denota qualquer mediação que possibilita e constrange fluxos de comunicação entre entidades ou processos. Contudo, no contexto de processos de significação material, a noção de interface adquire um significado específico que remete para a ideia de que a mente tem uma natureza essencialmente plástica e contígua à natureza do real — ou seja, que a natureza da realidade material afeta o fluxo temporal, as afeções e as fronteiras dos sistemas cognitivos (Malafouris, 2013, 245).

De modo a compreender como os artefactos podem ativar determinadas assemblagens que permitem o alinhamento dinâmico entre mente e mundo, cultura e

natureza, Malafouris recorre à neurociência e ao conceito de metaplasticidade, o qual designa a capacidade dinâmica de configuração da atividade sináptica. A metaplasticidade expressa-se na capacidade a longo-prazo de induzir a plasticidade neuronal, definindo padrões de potenciação ou depressão motivados pelas ações quotidianas que são estabelecidas com o mundo. Assim, a metaplasticidade descreve os processos em que a atividade sináptica, da qual dependem a aprendizagem e memória, é afetada e afeta os padrões estruturais que configuram essa capacidade plástica. As neurociências social e evolutiva concebem assim o cérebro como produto dinâmico de um processo de co-evolução contínuo, tal que o carácter mutável do real é contíguo com o tipo de modificações plásticas — funcionais, estruturais e anatómicas — do mesmo. O papel dos artefactos quotidianos transcende assim o âmbito da relação dicotómica entre sujeito e mundo, sendo esta relação significativa para a configuração a longo-prazo dos processos cognitivos que enquadram as percepções do real:

«Finally, things change the brain. They affect extensive structural rewiring by fine tuning existing brain pathways, by generating new connections within brain regions, or by transforming what was a useful brain function in one context into another function that is more useful in another context. More than that, things extend the functional architecture of the human cognitive system by adding new processing nodes to the system, or by changing the connections among existing nodes. More important, they are capable of transforming and rearranging the structure of a cognitive task, either by reordering the steps of a task or by delegating part of a cognitive process to another agent (human or artifact).» (Malafouris, 2013, 247)

Malafouris faz ainda referência à metaplasticidade como a possibilidade cognitiva de apreensão dos passos implicados numa tarefa, para a sua reordenação ou delegação sobre outro agente, estando assim em absoluta concordância com os conceitos de guião e delegação de Latour. Do mesmo modo que a arquitetura funcional do sistema cognitivo humano demonstra a capacidade de se reorganizar para desempenhar uma função em particular, assim estas interfaces se poderão reconfigurar em função do uso e contexto, para a execução de uma tarefa particular.



Tendo em consideração a particularidade destes objetos, é possível enquadrá-los no contexto de uma experiência cognitiva que dilui as fronteiras entre sujeito e mundo, considerando a relação com estas tecnologias não no sentido protético de aumento das capacidades humanas, mas segundo uma proposta de co-constituição contínua de agentes em relação e com igual possibilidade de mutação. Neste contexto, um qualquer quadro de análise que advogue esquemas rígidos para a articulação entre *sujeito* — *tecnologia* — *mundo* revela-se insuficiente para caracterizar a fluidez dos processos que os colocam em relação.

Assim, o percurso da investigação do Tangible Media Group, na busca pela integração contínua entre pessoas, informação digital e o ambiente físico em direção à visão *Radical Atoms*, tem um conjunto de implicações significativas nos processos de mediação tecnológica aberta por estes objetos:

(1) a passagem de um cenário em que *bits* e átomos se organizam estruturalmente, segundo um esquema de correspondências, para um cenário marcado pelo caráter processual das relações entre atores em rede;

(2) a passagem de um sistema de correspondências entre instâncias materiais e digitais para um modo de significação enativo, o qual difere deste esquema estrutural (próprio do signo linguístico), na medida em que existe uma relação de contiguidade entre o caráter do material e o caráter conceptual dos objetos;

(3) um modo específico de continuidade entre o que é a plasticidade do cérebro e dos processos cognitivos, e a capacidade de expressão dinâmica dos objetos desenvolvidos em função do horizonte dos *Radical Atoms*.

Dados os traços fundamentais desta relação co-constitutiva entre mente e realidade material, não é inusitado considerar os produtos da visão *Radical Atoms* nos termos de uma proposta para o desenho de artefactos tecnológicos que se alinha com esta fluidez entre agentes e estrutura, ideia e material, mente e mundo. Através da elisão destas fronteiras, estes sistemas de interação tangível sugerem a reorganização de alguns dos pressupostos fundamentais da teoria da mediação tecnológica, na medida em que dissolvem as categorias esquemáticas “sujeito”, “tecnologia” e “mundo”.

## CONCLUSÃO

Como argumentado ao longo da presente dissertação, o trabalho do Tangible Media Group, quando tomado no contexto da última edição da Ars Electronica, convida à sua localização no âmbito dos estudos dos media e, em particular, no seio das propostas da fenomenologia, filosofia da técnica e mediação tecnológica. Tendo sido notada a escassez de textos complementares da autoria dos programadores do festival que esclareçam e ativem estas relações, a presente dissertação procurou criar um espaço para o enquadramento do trabalho do Tangible Media Group no contexto dos estudos dos media, assim se propondo como uma leitura complementar ao tema da edição de 2016 *Radical Atoms: The Alchemists of Our Time*. Neste sentido, a dissertação não se focou na descrição das tecnologias em si, mas procurou antes refletir sobre os seus possíveis cenários de uso e o seu papel como mediadora de experiência.

Para o efeito, a dissertação desdobrou-se num esforço de (1) apresentação da visão do Tangible Media Group e da articulação entre os seus dois grandes projetos, *Tangible Bits* e *Radical Atoms*; (2) caracterização dos conceitos-chave evocados pelo trabalho do Tangible Media Group, que servem de pontos de contacto com os estudos dos media; (3) discussão das implicações destes objetos específicos sobre os processos de mediação tecnológica.

Em primeiro lugar, procurou-se compreender como se articulam os dois principais projetos de investigação do Tangible Media Group. Para o efeito, foi delimitado um *corpus* de análise de entre a vasta produção académica do grupo. O critério para a delimitação deste *corpus* foi oferecido pela própria Ars Electronica, através da cronologia publicada no catálogo do festival, a qual isola 31 projetos representativos do trabalho desenvolvido entre 1997 e 2016 pelo Tangible Media Group. Estes foram classificados em sete categorias que permitem compreender em detalhe a articulação entre os projetos *Tangible Bits* e *Radical Atoms*. Foi possível compreender que esta articulação acontece de forma orgânica e num ato auto-consciente das limitações de sistemas como os Table Top Tangibles para o desenho de experiências de

interação que envolvam os vários sentidos e capacidades natas do utilizador face aos ambientes quotidianos.

Em segundo lugar, foi necessário localizar quais os termos-chave que caracterizam o trabalho do Tangible Media Group, para determinar quais os pontos de contacto com os estudos dos media. Este exercício de recolha e análise permitiu isolar três grandes pontos de contacto, sintetizados em três termos: “ubíquo”, “superfície” e “forma”, os quais foram selecionados precisamente por evocarem questões afetas aos temas da fenomenologia, filosofia da tecnologia e mediação tecnológica. Para criar esta ponte, foi feito o levantamento exaustivo dos termos no *corpus* de análise, tendo em conta a palavra-chave em contexto, para depois proceder à sua localização no âmbito dos estudos dos media. Ao abordar as questões evocadas pelo trabalho do Tangible Media Group com base nos contributos dos estudos dos media, sublinhou-se como a articulação entre os dois projetos dialoga com as próprias limitações no seio dos temas da fenomenologia e filosofia da técnica, esclarecendo que as propriedades dos objetos e as experiências de interação desenvolvidos no contexto *Radical Atoms* reclamam um quadro de análise que corresponda à fluidez entre agentes e estrutura, ideia e material, mente e mundo que os mesmos sugerem.

Deste gesto de localização emergem alguns pontos de discussão que são particulares à interação com estes objetos, nomeadamente no que respeita à relação entre agentes, ao tipo de significação que veiculam e aos processos cognitivos em que são implicados. Para o efeito, é discutido um enquadramento que cruza a teoria ator-rede e a ideia de um signo enativo como chaves para uma experiência cognitiva que assenta na contiguidade entre mente e mundo. Estes sistemas de interação tangível sugerem assim a reorganização de alguns dos pressupostos fundamentais da teoria da mediação tecnológica, na medida em que dissolvem as categorias esquemáticas “sujeito”, “tecnologia” e “mundo”.

A mesma discussão permitiu ainda sublinhar como o desenvolvimento destes objetos revela uma preocupação significativa com o que serão os contextos de uso e a experiência resultante da interação com estas tecnologias, assim justificando a sua relevância para um evento como é o Festival Ars Electronica. O tema *Radical Atoms: The Alchemists of Our Time* sublinha que é fundamental a compreensão das tecnologias

emergentes para lá da sua estrutura técnica, potencial de inovação e diferencial competitivo no mercado, considerando também o seu papel participante nos fluxos simbólicos que informam a experiência humana. Por esta razão, o festival utiliza o tema para alinhar os estudos da interação humano-computador com um conjunto de ideias recentes originárias de disciplinas tão diversas como a teoria social, a semiótica e as neurociências.

Ao exibir o trabalho do Tangible Media Group lado a lado com uma seleção de objetos artísticos que evidencia a interação entre arte, ciência e tecnologia, a Ars Electronica destaca novas visões sobre o papel da investigação científica no panorama atual. Os “alquimistas do nosso tempo” são assim os agentes capazes de cruzar uma miríade de diferentes saberes e práticas no sentido de conceber o futuro da relação com a tecnologia — e, tal como se evidencia ao longo da presente dissertação, os investigadores do Tangible Media Group oferecem um exemplo signifiicante destas práticas. Por fim, o âmbito destes trabalhos abre ainda o caminho para o que é o tema da próxima edição da Ars Electronica: *Artificial Intelligence: The Other I*, o qual propõe conceber o papel dos métodos de Inteligência Artificial — *deep learning*, redes neuronais com capacidade de auto-aprendizagem, *robots* autónomos, assistentes digitais... — no contexto de continuidade e co-constituição de atores, numa abordagem que considere não apenas as suas repercussões económicas, uma vez mais abrindo o espaço de discussão para as dimensões culturais, psicológicas e filosóficas da tecnologia.

## BIBLIOGRAFIA

Ars Electronica (2016) Radical Atoms Exhibition [artigo website]. Consultado em <http://www.aec.at/radicalatoms/en/radical-atoms-exhibition/>.

Ars Electronica (2017) Ars Electronica Festival 2017: AI – Das andere Ich / The Other I [artigo website]. Consultado em <https://www.aec.at/ai/en/theme/>.

Ars Electronica (2016, October 25) *Ars Electronica Festival: RADICAL ATOMS and the alchemists of our time / EN* [Video], Consultado em <https://www.youtube.com/watch?v=gjMdtWfCjuQ>.

Bergström, J. et al. (2010) *Becoming materials: material forms and forms of practice*, *Digital Creativity*, 21(3), 155-172.

Blackshaw, M et al. (2011) Recompose: direct and gestural interaction with an actuated surface, *Proceedings of the 2011 annual conference extended abstracts on Human factors in computing systems*, 1237-1242.

Bolter D. J. e Gromala, D. (2003) *Windows and Mirrors: Interaction Design, Digital Art, and the Myth of Transparency*. Cambridge: MIT Press.

Brand, S. (1987) *The Media Lab: inventing the future at MIT*. New York: Viking.

Brave, S. et al. (1993) Tangible Interfaces for Remote Collaboration and Communication, *Proceedings of the 1998 ACM conference on computer supported cooperative work (CSCW'98)*, 169 - 178.

Brave, S. e Dahley, A. (1997) inTouch: a medium for haptic interpersonal communication, *CHI '97 Extended Abstracts on Human Factors in Computing Systems: Looking To the Future*, 363-364.

David, L. e Hiroshi, I. (2012) Towards Radical Atoms — Form-giving to transformable materials, *Proceedings of Cognitive Infocommunications (CogInfoCom), 2012 IEEE 3rd International Conference*, Kosice, Slovakia.

Engelbart, D e English, W. (1968) A research center for augmenting human intellect, *Conference Proceedings of the 1968 Fall Joint Computer Conference*, 395-410.

Fitzmaurice, G. (1996) *Graspable User Interfaces* (dissertação de doutoramento). Consultado em: <http://www.dgp.toronto.edu/~gf/papers/PhD%20-%20Graspable%20UIs/Thesis.gf.html>.

Flusser, V. (1999) *The Shape of Things: A Philosophy of Design*. London: Reaktion Books.

Follmer, S. (2012) Jamming user interfaces: programmable particle stiffness and sensing for malleable and shape-changing devices, *Proceedings of the 25th annual ACM symposium on User interface software and technology (UIST '12)*, 519-528.

Follmer, S. (2013) inFORM: Dynamic Physical Affordances and Constraints through Shape and Object Actuation, *Proceedings of the 26th annual ACM symposium on User interface software and technology (UIST '13)*, 417-426.

Frei, P. (2000) Curlybot: designing a new class of computational toys, *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems*, 129-136.

Friedberg, A. (2006) *The Virtual Window: from Alberti to Microsoft*. Cambridge: MIT Press.

Gibson, J. (1986) *The Theory of Affordances, Perceiving, Acting, and Knowing*. New Jersey: Erlbaum.

Heibeck, F. et al. (2015) uniMorph: Fabricating Thin Film Composites for Shape-Changing Interfaces, *Proceedings of the 28th Annual ACM Symposium on User Interface Software & Technology*, 233-242.

Heidegger, M. (1977) *The question concerning technology, and other essays*. New York: Harper & Row.

Ihde, D. (1979) *Technics and Praxis*. Dordrecht: Reidel Publishing Company.

Ishii, H. e Ullmer, B. (1997) Tangible bits: towards seamless interfaces between people, bits, and atoms, *Proceedings of the CHI'97 conference on human factors in computing systems*, 234-241.

Ishii, H. et al. (2001) Bottles as a minimal interface to access digital information, *Extended Abstracts on Human Factors in Computing Systems (CHI EA '01)*, 187-188.

Ishii, H. et al. (2004) Bringing Clay and Sand into Digital Design — Continuous Tangible user Interfaces, *BT Technology Journal* 22(4), 287-299.

Ishii, H. et at. (2012) Radical Atoms: Beyond Tangible Bits, Toward Transformable Materials, *Interactions*, 19(1), 38-51.

Ishii, H. et al. (2015) TRANSFORM: Embodiment of “Radical Atoms” at Milano Design Week”, *Proceedings of the 33rd Annual ACM Conference Extended Abstracts on Human Factors in Computing Systems*, 687-694.

Kay, A. (1972) A Personal Computer for Children of All Ages, *Proceedings of the ACM National Conference*. New York: ACM.

Latour, B. (1994) On Technical Mediation, *Common Knowledge*, 3(2), 29-64.

Latour, B. (2005). *Reassembling the social: An introduction to actor-network-theory*. Oxford: Oxford University Press.

Lee, J. et al (2011) ZeroN: mid-air tangible interaction enabled by computer controlled magnetic levitation, *Proceedings of the 24th annual ACM symposium on User interface software and technology (UIST '11)*, 327-336.

Leithinger, D. e Ishii, H. (2010) Relief: a scalable actuated shape display, *Proceedings of the Fourth international Conference on Tangible, Embedded, and Embodied interaction*, 221-222.

Leithinger, D. et al. (2013) Sublimate: state-changing virtual and physical rendering to augment interaction with shape displays, *Proceedings of the 2013 ACM annual conference on Human factors in computing systems (CHI '13)*, 1441-1450.

Licklider, J.C.R. e Taylor, R. (1968) The Computer as a Communications Device, *Science and Technology* (76), 21-31.

Malafouris, L. (2013) *How Things Shape the Mind: a Theory of Material Engagement*. Cambridge: MIT Press.

Manovich, L. (2001) *The Language of New Media*. Cambridge: MIT Press.

Manzini, E. (1989) *The Material of Invention: Materials and Design*. Cambridge, USA: MIT Press.

McGoogan, C. (15 de Outubro, 2015) The MIT Media Lab is waging war on pixels, Wired. Consultado em: <http://www.wired.co.uk/article/hiroshi-ishii-wired-2015>.

MIT Tangible Media Group, Our Vision. Consultado em: <http://tangible.media.mit.edu/vision/>.

Nakagaki, K. et al. (2015) LineFORM: Actuated Curve Interfaces for Display, Interaction, and Constraint, *Proceedings of the 28th annual ACM Symposium on User Interface Software and Technology (UIST '15)*, 333-339.

Nakagaki, K. et al. (2016) ChainFORM: A Linear Integrated Modular Hardware System for Shape Changing Interfaces, *Proceedings of the 29th Annual Symposium on User Interface Software and Technology (UIST '16)*, 87-96.

Nakagaki, K. et al. (2016) Materiable: Rendering Dynamic Material Properties in Response to Direct Physical Touch with Shape Changing Interfaces, *Proceedings of the 34th Annual ACM Conference on Human Factors in Computing Systems (CHI '16)*, 2764-2772.

Nelson, T. H. (1987) *Computer lib; dream machines*. Redmond, Wash: Tempus Books of Microsoft Press.

Norman, D. (2006) *The Design of Everyday Things*. New York: Basic Books.

Ou, J. et al. (2014) jamSheets: thin interfaces with tunable stiffness enabled by layer jamming, *Proceedings of the 8th International Conference on Tangible, Embedded and Embodied Interaction (TEI '14)*, 65-72.

Ou, J. et al. (2016) Cillia: 3D Printed Micro-Pillar Structures for Surface Texture, Actuation and Sensing, *Proceedings of the 2016 CHI Conference on Human Factors in Computing Systems (CHI '16)*, 5753-5764.

Pangaro, G. et al. (2003) The Actuated Workbench: Computer-Controlled Actuation in Tabletop Interfaces, *ACM Transactions on Graphics*, 22 (3), 689-699.

Panofsky, E. (1991) *Perspective as Symbolic Form*. New York: Zone Books.

Parkes, A. e Ishii, H. (2009) Kinetic sketchup: motion prototyping in the tangible design process, *Proceedings of the 3rd International Conference on Tangible and Embedded Interaction*, 367-372.

Parkes, A. e Ishii, H. (2010) Bosu: a physical programmable design tool for transformability with soft mechanics, *Proceedings of the 8th ACM Conference on Designing Interactive Systems*, 189-198.

Patten, J. et al. (2001) Sensetable: a wireless object tracking platform for tangible user interfaces, *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems*, 253-260.

Patten, J. e Ishii, H (2007) Mechanical constraints as computational constraints in tabletop tangible interfaces, *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems (CHI '07)*, 809-818.

Piper, B. et al. (2002) Illuminating clay: a 3-D tangible interface for landscape analysis, *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems: Changing Our World, Changing Ourselves*, 355-362.

Plant, S. (1997) *Zeros ones: women, cyberspace and the new sexual revolution*. London: Fourth Estate.



Raffle, H. et al. (2004) Topobo: a constructive assembly system with kinetic memory, *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems (CHI '04)*, 647-654.

Siegert, B. (2015) *Cultural Techniques: Grids, Filters, Doors, and Other Articulations of the Real*. New York: Fordham University Press.

Schoessler, P. et al. (2015) Kinetic Blocks - Actuated Constructive Assembly for Interaction and Display, *Proceedings of the 28th annual ACM symposium on User interface software and technology (UIST '15)*, 341-349.

Tognazzini, B. (1993) Principles, techniques, and ethics of stage magic and their application to human interface design, *CHI '93 Proceedings of the INTERACT '93 and CHI '93 Conference on Human Factors in Computing Systems*, 355-362.

Ullmer, B. (1997) *Models and Mechanisms for Tangible User Interfaces*. (dissertação de bacharelato). Consultado em: <https://tangible-fmp.mit.edu/publishedmedia/Papers/324-Models%20and%20Mechanisms%20for/Published/PDF>

Ullmer, B. e Ishii, H. (1997) The metaDESK: models and prototypes for tangible user interfaces, *Proceedings of the 10th Annual ACM Symposium on User interface Software and Technology (UIST '97)*, 223-232.

Underkoffler, J. e Ishii, H. (1999) Urp: a luminous-tangible workbench for urban planning and design, *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems: the CHI Is the Limit*, 386-393.

Vallgård, A. (2014) Giving form to computational things: developing a practice of interaction design, *Personal Ubiquitous Computing* 1(3), 577-592.

Verbeek, P. (1992) *What Things Do: Philosophical Reflections on Technology, Agency and Design*. Pennsylvania: Pennsylvania State University Press.

Verbeek, P. e Kockelkoren, P. (1998) The Things that Matter, *Design Issues* 14:3, 28-42.

Want et al. (1995) An Overview of the PARCTab Ubiquitous Experiment, *IEEE Personal Communications* (2), 28-43.

Weiser, M. (1991) The Computer of the 21st Century, *Mobile Computing and Communications Review* (3:3), 3-11.

Wisneski, C. A. (1997) *The Design of Personal Ambient Displays* (dissertação de bacharelato). Consultado em: <http://tmg-trackr.media.mit.edu/publishedmedia/Papers/298-The%20Design%20of%20Personal/Published/PDF>.

Yao, L. et al. (2014) Integrating optical waveguides for display and sensing on pneumatic soft shape changing interfaces, *Proceedings of the adjunct publication of the 27th annual ACM symposium on User interface software and technology (UIST'14 Adjunct)*, 117-118.

Yao, L. (2015) bioLogic: Natto Cells as Nanoactuators for Shape Changing Interfaces, *Proceedings of the 33rd Annual ACM Conference on Human Factors in Computing Systems (CHI '15)*, 1-10.

## LISTA DE FIGURAS

Fig. 1 — <i>musicBottles</i> (1999), Tangible Media Group / MIT Media Lab .....	32
Fig. 2 — <i>Urp</i> (2000), Tangible Media Group / MIT Media Lab .....	38
Fig. 3 — <i>Sandscape</i> (1999), Tangible Media Group / MIT Media Lab .....	39
Fig. 4 — <i>inFORM</i> (2013), Tangible Media Group / MIT Media Lab .....	40
Fig. 5 — <i>PneUI</i> (2013), Tangible Media Group / MIT Media Lab .....	43
Fig. 6 — <i>bioLogic</i> (2015), Tangible Media Group / MIT Media Lab .....	44
Fig. 7 — <i>ChainFORM</i> (2016), Tangible Media Group / MIT Media Lab .....	45

## ANEXO 1

### CORPUS DE ANÁLISE

Projeto	Categoria	Artigo	Palavras-chave	
metaDESK	Table Top Tangibles	Ullmer, B. e Ishii, H. (1997). The metaDESK: models and prototypes for tangible user interfaces, <i>Proceedings of the 10th Annual ACM Symposium on User interface Software and Technology (UIST '97)</i> , 223-232.	tangible user interfaces, input devices, haptic input, augmented reality, ubiquitous computing	<a href="https://tangible-fmp.mit.edu/publishedmedia/Papers/322-The%20metaDESK%20Models%20and/Published/PDF">https://tangible-fmp.mit.edu/publishedmedia/Papers/322-The%20metaDESK%20Models%20and/Published/PDF</a>
PSyBench	Actuated Table Top Tangibles	Brave et al. (1993) Tangible Interfaces for Remote Collaboration and Communication, <i>Proceedings of the 1998 ACM conference on computer supported cooperative work (CSCW'98)</i> , 169 - 178.	tangible Interfaces, haptic interfaces, telemanipulation, force-feedback, physical presence	<a href="https://tangible-fmp.mit.edu/publishedmedia/Papers/315-Tangible%20Interfaces%20for%20Remote/Published/PDF">https://tangible-fmp.mit.edu/publishedmedia/Papers/315-Tangible%20Interfaces%20for%20Remote/Published/PDF</a>
inTouch	Kinetic Materials	Brave, S. e Dahley, A. (1997) inTouch: a medium for haptic interpersonal communication, <i>CHI '97 Extended Abstracts on Human Factors in Computing Systems: Looking To the Future</i> , 363-364.	haptics, interpersonal communication, force feedback, telepresence	<a href="https://tangible-fmp.mit.edu/publishedmedia/Papers/329-inTouch%20A%20Medium%20for/Published/PDF">https://tangible-fmp.mit.edu/publishedmedia/Papers/329-inTouch%20A%20Medium%20for/Published/PDF</a>
musicBottles	Table Top Tangibles	Ishii, H., et al. (2001) Bottles as a minimal interface to access digital information, <i>Extended Abstracts on Human Factors in Computing Systems (CHI EA '01)</i> , 187-188.	interaction design, ubiquitous, tangible interface, aesthetic interface, containers, controls	<a href="https://tangible-fmp.mit.edu/publishedmedia/Papers/466-Bottles%20as%20a%20minimal/Published/PDF">https://tangible-fmp.mit.edu/publishedmedia/Papers/466-Bottles%20as%20a%20minimal/Published/PDF</a>
CurlyBot	Kinetic Materials	Frei, P. (2000). curlybot: designing a new class of computational toys, <i>Proceedings of the SIGCHI Conference on Human Factors in Computing Systems</i> , 129-136.	education, learning, children, tangible interface, toy	<a href="https://tangible-fmp.mit.edu/publishedmedia/Papers/433-curlybot%20Designing%20a%20New/Published/PDF">https://tangible-fmp.mit.edu/publishedmedia/Papers/433-curlybot%20Designing%20a%20New/Published/PDF</a>
Urp	Table Top Tangibles	Underkoffler, J. e Ishii, H. (1999) Urp: a luminous-tangible workbench for urban planning and design, <i>Proceedings of the SIGCHI Conference on Human Factors in Computing Systems: the CHI Is the Limit</i> , 386-393.	urban design, urban planning, architectural simulation, luminous-tangible interface, direct manipulation, augmented reality, prototyping tool, interactive projection, tangible bits	<a href="https://tangible-fmp.mit.edu/publishedmedia/Papers/307-Urp%20A%20LuminousTangible/Published/PDF">https://tangible-fmp.mit.edu/publishedmedia/Papers/307-Urp%20A%20LuminousTangible/Published/PDF</a>

Projeto	Categoria	Artigo	Palavras-chave	
<b>Sensetable</b>	Table Top Tangibles	Patten, J. et al. (2001) Sensetable: a wireless object tracking platform for tangible user interfaces, <i>Proceedings of the SIGCHI Conference on Human Factors in Computing Systems</i> , 253-260.	tangible user interface, interactive surface, object tracking, two-handed manipulation, system dynamics, augmented reality	<a href="https://tangible-fmp.mit.edu/publishedmedia/Papers/293-Sensetable%20A%20Wireless%20Object/Published/PDF">https://tangible-fmp.mit.edu/publishedmedia/Papers/293-Sensetable%20A%20Wireless%20Object/Published/PDF</a>
<b>Actuated Workbench</b>	Actuated Table Top Tangibles	Pangaro, G. et al. (2003) The Actuated Workbench: Computer-Controlled Actuation in Tabletop Interfaces. <i>ACM Transactions on Graphics</i> , 22 (3), 689-699.	tangible user interfaces, physical interaction, actuation, synchronization, interactive surface, object tracking, computer supported cooperative work	<a href="https://tangible-fmp.mit.edu/publishedmedia/Papers/225-The%20Actuated%20Workbench%20Computer/Published/PDF">https://tangible-fmp.mit.edu/publishedmedia/Papers/225-The%20Actuated%20Workbench%20Computer/Published/PDF</a>
<b>Illuminating Clay</b>	Deformable Tangibles	Piper, B. et al. (2002) Illuminating clay: a 3-D tangible interface for landscape analysis, <i>Proceedings of the SIGCHI Conference on Human Factors in Computing Systems: Changing Our World, Changing Ourselves</i> , 355-362.	tangible user interface, 3D laser scanner, landscape design, physical models, GIS, DEM	<a href="https://tangible-fmp.mit.edu/publishedmedia/Papers/266-Illuminating%20Clay%20A%203/Published/PDF">https://tangible-fmp.mit.edu/publishedmedia/Papers/266-Illuminating%20Clay%20A%203/Published/PDF</a>
<b>SandScape</b>	Deformable Tangibles	Ishii, H. et al. (2004) Bringing Clay and Sand into Digital Design — Continuous Tangible user Interfaces, <i>BT Technology Journal</i> , 22(4), 287-299.	n.a.	<a href="https://tangible-fmp.mit.edu/publishedmedia/Papers/188-Bringing%20clay%20and%20sand/Published/PDF">https://tangible-fmp.mit.edu/publishedmedia/Papers/188-Bringing%20clay%20and%20sand/Published/PDF</a>
<b>PICO</b>	Actuated Table Top Tangibles	Patten, J. e Ishii, H (2007) Mechanical constraints as computational constraints in tabletop tangible interfaces, <i>Proceedings of the SIGCHI Conference on Human Factors in Computing Systems (CHI '07)</i> , 809-818.	tangible interfaces, physical interaction, interactive surface, improvisation, actuation	<a href="https://tangible-fmp.mit.edu/publishedmedia/Papers/131-Mechanical%20Constraints%20as%20Computational/Published/PDF">https://tangible-fmp.mit.edu/publishedmedia/Papers/131-Mechanical%20Constraints%20as%20Computational/Published/PDF</a>
<b>Topobo</b>	Kinetic Materials	Raffle, H. et al. (2004) Topobo: a constructive assembly system with kinetic memory, <i>Proceedings of the SIGCHI Conference on Human Factors in Computing Systems (CHI '04)</i> , 647-654.	digital manipulative, education, toy, learning, children, modular robotics, programming by demonstration, tangible interface	<a href="https://tangible-fmp.mit.edu/publishedmedia/Papers/187-Topobo%20A%20Constructive%20Assembly/Published/PDF">https://tangible-fmp.mit.edu/publishedmedia/Papers/187-Topobo%20A%20Constructive%20Assembly/Published/PDF</a>
<b>Kinetic Sketchup</b>	Kinetic Materials	Parkes, A. e Ishii, H. (2009) Kinetic sketchup: motion prototyping in the tangible design process, <i>Proceedings of the 3rd International Conference on Tangible and Embedded Interaction</i> , 367-372.	Tangible User Interface, Kinetic Design, Transformability, Product Design, Architecture	<a href="http://dl.acm.org/citation.cfm?id=1517738">http://dl.acm.org/citation.cfm?id=1517738</a>

Projeto	Categoria	Artigo	Palavras-chave	
<b>Bosu</b>	Kinetic Materials	Parkes, A. e Ishii, H. (2010) Bosu: a physical programmable design tool for transformability with soft mechanics, <i>Proceedings of the 8th ACM Conference on Designing Interactive Systems</i> , 189-198.	tangible user interface, kinetic interface, transformability, case studies, product design, interaction design	<a href="http://dl.acm.org/citation.cfm?id=1858205">http://dl.acm.org/citation.cfm?id=1858205</a>
<b>Relief</b>	Dynamic Shape Displays	Leithinger, D. e Ishii, H. (2010) Relief: a scalable actuated shape display, <i>Proceedings of the Fourth international Conference on Tangible, Embedded, and Embodied interaction</i> , 221-222.	pin array, haptic display, tangible input, shape display, relief interface	<a href="https://tangible-fmp.mit.edu/publishedmedia/Papers/432-Relief%20A%20Scalable%20Actuated/Published/PDF">https://tangible-fmp.mit.edu/publishedmedia/Papers/432-Relief%20A%20Scalable%20Actuated/Published/PDF</a>
<b>Recompose</b>	Dynamic Shape Displays	Blackshaw, M et al. (2011) Recompose: direct and gestural interaction with an actuated surface, <i>Proceedings of the 2011 annual conference extended abstracts on Human factors in computing systems</i> , 1237-1242.	gestural input, tangible input, direct manipulation, actuated surface, shape display	<a href="https://tangible-fmp.mit.edu/publishedmedia/Papers/450-Recompose%20Direct%20and%20Gestural/Published/PDF">https://tangible-fmp.mit.edu/publishedmedia/Papers/450-Recompose%20Direct%20and%20Gestural/Published/PDF</a>
<b>ZeroN</b>	Levitating Materials	Lee, J. et al (2011) ZeroN: mid-air tangible interaction enabled by computer controlled magnetic levitation, <i>Proceedings of the 24th annual ACM symposium on User interface software and technology (UIST '11)</i> , 327-336.	tangible Interfaces, 3D UI	<a href="https://tangible-fmp.mit.edu/publishedmedia/Papers/477-ZeroN%20Midair%20Tangible/Published/PDF">https://tangible-fmp.mit.edu/publishedmedia/Papers/477-ZeroN%20Midair%20Tangible/Published/PDF</a>
<b>JammingUI</b>	Programmable Materials	Follmer, S. (2012) Jamming user interfaces: programmable particle stiffness and sensing for malleable and shape-changing devices, <i>Proceedings of the 25th annual ACM symposium on User interface software and technology (UIST '12)</i> , 519-528.	jamming, variable stiffness, organic user interfaces, malleable input, haptic feedback	<a href="https://tangible-fmp.mit.edu/publishedmedia/Papers/484-Jamming%20User%20Interfaces%20Programmable/Published/PDF">https://tangible-fmp.mit.edu/publishedmedia/Papers/484-Jamming%20User%20Interfaces%20Programmable/Published/PDF</a>
<b>inFORM</b>	Dynamic Shape Displays	Follmer, S. (2013) inFORM: Dynamic Physical Affordances and Constraints through Shape and Object Actuation, <i>Proceedings of the 26th annual ACM symposium on User interface software and technology (UIST '13)</i> , 417-426.	shape-changing user interfaces, shape displays, actuated tangible interfaces, token and constraint interfaces	<a href="https://tangible-fmp.mit.edu/publishedmedia/Papers/527-inFORM%20Dynamic%20Physical%20Affordances/Published/PDF">https://tangible-fmp.mit.edu/publishedmedia/Papers/527-inFORM%20Dynamic%20Physical%20Affordances/Published/PDF</a>

Projeto	Categoria	Artigo	Palavras-chave	
<b>SUBLIMATE</b>	Dynamic Shape Displays	Leithinger, D. et al. (2013) Sublimate: state-changing virtual and physical rendering to augment interaction with shape displays, <i>Proceedings of the 2013 ACM annual conference on Human factors in computing systems (CHI '13)</i> , 1441-1450.	shape display, actuated tangibles, spatial augmented reality, 3D interaction	<a href="https://tangible-fmp.mit.edu/publishedmedia/Papers/513-Sublimate%20StateChanging%20Virtual/Published/PDF">https://tangible-fmp.mit.edu/publishedmedia/Papers/513-Sublimate%20StateChanging%20Virtual/Published/PDF</a>
<b>PneUI</b>	Programmable Materials	Yao, L. (2013) PneUI: pneumatically actuated soft composite materials for shape changing interfaces, <i>Proceedings of the 26th annual ACM symposium on User interface software and technology (UIST '13)</i> , 13-22.	soft composite material, pneumatic system, soft actuator, soft robotics, human-material interaction, shape changing interface, radical atoms, organic user interface	<a href="https://tangible-fmp.mit.edu/publishedmedia/Papers/528-PneUI%20Pneumatically%20Actuated%20Soft/Published/PDF">https://tangible-fmp.mit.edu/publishedmedia/Papers/528-PneUI%20Pneumatically%20Actuated%20Soft/Published/PDF</a>
<b>JamSheets</b>	Programmable Materials	Ou, J. et al. (2014) jamSheets: thin interfaces with tunable stiffness enabled by layer jamming, <i>Proceedings of the 8th International Conference on Tangible, Embedded and Embodied Interaction (TEI '14)</i> , 65-72.	jamming, variable stiffness, organic user interfaces, flexible interfaces, haptic feedback	<a href="https://tangible-fmp.mit.edu/publishedmedia/Papers/540-jamSheets%20Thin%20Interfaces%20with/Published/PDF">https://tangible-fmp.mit.edu/publishedmedia/Papers/540-jamSheets%20Thin%20Interfaces%20with/Published/PDF</a>
<b>OptiElastic</b>	Programmable Materials	Yao, L. et al. (2014) Integrating optical waveguides for display and sensing on pneumatic soft shape changing interfaces, <i>Proceedings of the adjunct publication of the 27th annual ACM symposium on User interface software and technology (UIST'14 Adjunct)</i> , 117-118.	n.a.	<a href="https://tangible-fmp.mit.edu/publishedmedia/Papers/566-Integrating%20Optical%20Waveguides%20for/Published/PDF">https://tangible-fmp.mit.edu/publishedmedia/Papers/566-Integrating%20Optical%20Waveguides%20for/Published/PDF</a>
<b>LineFORM</b>	Kinetic Materials	Nakagaki, K. et al. (2015) LineFORM: Actuated Curve Interfaces for Display, Interaction, and Constraint, <i>Proceedings of the 28th annual ACM Symposium on User Interface Software and Technology (UIST '15)</i> , 333-339.	shape-changing interfaces, tangible user Interfaces, curves	<a href="https://tangible-fmp.mit.edu/publishedmedia/Papers/583-LineFORM%20Actuated%20Curve%20Interfaces/Published/PDF">https://tangible-fmp.mit.edu/publishedmedia/Papers/583-LineFORM%20Actuated%20Curve%20Interfaces/Published/PDF</a>
<b>bioLogic</b>	Programmable Materials	Yao, L. et al. (2015) bioLogic: Natto Cells as Nanoactuators for Shape Changing Interfaces, <i>Proceedings of the 33rd Annual ACM Conference on Human Factors in Computing Systems (CHI '15)</i> , 1-10.	biology, biological material, shape changing interfaces, smart material, programmable material, bio-printing, hygromorph	<a href="https://tangible-fmp.mit.edu/publishedmedia/Papers/564-bioLogic%20Natto%20Cells%20as/Published/PDF">https://tangible-fmp.mit.edu/publishedmedia/Papers/564-bioLogic%20Natto%20Cells%20as/Published/PDF</a>

Projeto	Categoria	Artigo	Palavras-chave	
<b>UniMorph</b>	Programmable Materials	Heibeck, F. et al. (2015) uniMorph: Fabricating Thin Film Composites for Shape-Changing Interfaces, <i>Proceedings of the 28th Annual ACM Symposium on User Interface Software &amp; Technology</i> , 233-242.	shape-changing interfaces, unimorph actuation, digital fabrication, rapid prototyping, human-material interaction, organic user interface, radical atoms	<a href="https://tangible-fmp.mit.edu/publishedmedia/Papers/592-uniMorph%20%20Fabricating%20Thin%20Film/Published/PDF">https://tangible-fmp.mit.edu/publishedmedia/Papers/592-uniMorph%20%20Fabricating%20Thin%20Film/Published/PDF</a>
<b>TRANSFORM</b>	Dynamic Shape Displays	Ishii, H. et al. (2015) TRANSFORM: Embodiment of “Radical Atoms” at Milano Design Week”, <i>Proceedings of the 33rd Annual ACM Conference Extended Abstracts on Human Factors in Computing Systems</i> , 687-694.	tangible user interfaces, radical atoms, shape display, shape changing interfaces, design	<a href="https://tangible-fmp.mit.edu/publishedmedia/Papers/554-TRANSFORM%20Embodiment%20of%20Radical/Published/PDF">https://tangible-fmp.mit.edu/publishedmedia/Papers/554-TRANSFORM%20Embodiment%20of%20Radical/Published/PDF</a>
<b>Kinetic Blocks</b>	Dynamic Shape Displays	Schoessler, P. et al. (2015) Kinetic Blocks - Actuated Constructive Assembly for Interaction and Display, <i>Proceedings of the 28th annual ACM symposium on User interface software and technology (UIST '15)</i> , 341-349.	shape-changing user interfaces, shape displays, actuated tangible interfaces	<a href="https://tangible-fmp.mit.edu/publishedmedia/Papers/584-Kinetic%20Blocks%20%20Actuated%20Constructive/Published/PDF">https://tangible-fmp.mit.edu/publishedmedia/Papers/584-Kinetic%20Blocks%20%20Actuated%20Constructive/Published/PDF</a>
<b>ChainFORM</b>	Kinetic Materials	Nakagaki, K. et al. (2016) ChainFORM: A Linear Integrated Modular Hardware System for Shape Changing Interfaces, <i>Proceedings of the 29th Annual Symposium on User Interface Software and Technology (UIST '16)</i> , 87-96.	actuated curve interfaces, shape changing interfaces, modular robotics	<a href="https://tangible-fmp.mit.edu/publishedmedia/Papers/619-ChainFORM%20A%20Linear%20Integrated/Published/PDF">https://tangible-fmp.mit.edu/publishedmedia/Papers/619-ChainFORM%20A%20Linear%20Integrated/Published/PDF</a>
<b>Cillia</b>	Programmable Materials	Ou, J. et al. (2016) Cillia: 3D Printed Micro-Pillar Structures for Surface Texture, Actuation and Sensing, <i>Proceedings of the 2016 CHI Conference on Human Factors in Computing Systems (CHI '16)</i> , 5753-5764.	3D printing, surface texture, actuated interfaces, acoustic sensing, digital fabrication, hair	<a href="https://tangible-fmp.mit.edu/publishedmedia/Papers/607-Cillia%20%203D%20Printed%20Micro/Published/PDF">https://tangible-fmp.mit.edu/publishedmedia/Papers/607-Cillia%20%203D%20Printed%20Micro/Published/PDF</a>
<b>Materiable</b>	Dynamic Shape Displays	Nakagaki, K. et al. (2016) Materiable: Rendering Dynamic Material Properties in Response to Direct Physical Touch with Shape Changing Interfaces, <i>Proceedings of the 34th Annual ACM Conference on Human Factors in Computing Systems (CHI '16)</i> , 2764-2772.	rendered material properties, shape changing interface, physics simulation, pin-based shape display	<a href="https://tangible-fmp.mit.edu/publishedmedia/Papers/598-Materiable%20Rendering%20Dynamic%20Material/Published/PDF">https://tangible-fmp.mit.edu/publishedmedia/Papers/598-Materiable%20Rendering%20Dynamic%20Material/Published/PDF</a>



## ANEXO 2

### PALAVRAS-CHAVE — VISTA GERAL

Ano	Palavras-chave
1997	tangible user interfaces input devices haptic input augmented reality ubiquitous computing haptics interpersonal communication force feedback telepresence
1998	tangible interfaces haptic interfaces telem Manipulation force-feedback physical presence
1999	urban design urban planning architectural simulation luminous-tangible interface direct manipulation augmented reality prototyping tool interactive projection tangible bits
2000	education children tangible interface toy learning
2001	interaction design ubiquitous tangible interface aesthetic interface containers controls tangible user interface interactive surface object tracking two-handed manipulation system dynamics augmented reality
2002	tangible user interfaces physical interaction actuation, synchronization interactive surface object tracking computer supported cooperative work tangible user interface 3D laser scanner landscape design physical models GIS DEM
2003	n.a.

2004	digital manipulative education toy learning children modular robotics programming by demonstration tangible interface
2005	n.a.
2006	n.a.
2007	tangible interfaces physical interaction interactive surface improvisation actuation
2008	n.a.
2009	tangible user interface kinetic design transformability product design architecture
2010	tangible user interface kinetic interface transformability case studies product design interaction design pin array haptic display tangible input shape display relief interface
2011	gestural input tangible input direct manipulation actuated surface shape display tangible Interfaces 3D UI
2012	jamming variable stiffness organic user interfaces malleable input haptic feedback
2013	shape-changing user interfaces shape displays actuated tangible interfaces token and constraint interfaces shape display actuated tangibles spatial augmented reality 3D interaction soft composite material pneumatic system soft actuator soft robotics human-material interaction shape changing interface radical atoms organic user interface
2014	jamming variable stiffness organic user interfaces flexible interfaces haptic feedback

2015	shape-changing interfaces tangible user Interfaces curves biology biological material shape changing interfaces smart material programmable material bio-printing, hygromorph shape-changing interfaces unimorph actuation digital fabrication rapid prototyping human-material interaction organic user interface radical atoms tangible user interfaces radical atoms shape display shape changing interfaces design shape-changing user interfaces shape displays actuated tangible interfaces
2016	actuated curve interfaces shape changing interfaces modular robotics 3D printing surface texture actuated interfaces acoustic sensing digital fabrication hair rendered material properties shape changing interface physics simulation pin-based shape display

## ANEXO 3

### TERMOS SELECIONADOS — PALAVRA-CHAVE EM CONTEXTO

#### Ubíquo (*Ubiquitous*)

Código	Palavra-chave	Projeto	Palavra-chave em contexto
UB. 1	ubiquitous	metaDESK	The research themes of augmented reality and ubiquitous computing are also important motivators to the TUI approach, but are marked by important differences.
UB. 2	ubiquitous	metaDESK	The pioneering Xerox PARC work in ubiquitous computing by Weiser et al. explored manners by which many computational devices could be distributed and integrated within the physical environment.
UB. 3	ubiquitous	musicBottles	Mark Weiser's vision of Ubiquitous Computing proposes a world in which computational services can be naturally and "invisibly" integrated into our physical environment.
UB. 4	ubiquitous	musicBottles	Our search converged on ubiquitous glass bottles.
UB. 5	ubiquitous	uniMorph	To demonstrate the wide applicability of uniMorph, we present several applications in ubiquitous and mobile computing.

#### Superfície (*Surface*)

Código	Palavra-chave	Projeto	Palavra-chave em contexto
SP. 1	surface	metaDESK	... "Tangible User Interfaces" (TUIs) – user interfaces employing physical objects, instruments, surfaces, and spaces as physical interfaces to digital information.
SP. 2	surface	metaDESK	... the desk, a nearly-horizontal back-projected graphical surface; the active lens, an arm-mounted flat-panel display; the passive lens, an optically transparent surface through which the desk projects; and an assortment of physical objects and instruments which are used on desk's surface.
SP. 3	surface	metaDESK	... the desk, a nearly-horizontal back-projected graphical surface; the active lens, an arm-mounted flat-panel display; the passive lens, an optically transparent surface through which the desk projects; and an assortment of physical objects and instruments which are used on desk's surface.
SP. 4	surface	metaDESK	... the desk, a nearly-horizontal back-projected graphical surface; the active lens, an arm-mounted flat-panel display; the passive lens, an optically transparent surface through which the desk projects; and an assortment of physical objects and instruments which are used on desk's surface.
SP. 5	surface	metaDESK	We give the GUI "window" device substance as a physical "lens" which may be hand-held, arm-mounted, or placed upon another surface.
SP. 6	surface	metaDESK	... each supporting interaction with a large graphical surface viewable in stereo 3D using LCD shutterglass eyepieces.
SP. 7	surface	metaDESK	Several physical objects and instruments for interacting with geographical space sit in a translucent holding tray on the metaDESK's surface.
SP. 8	surface	metaDESK	The Dome phicon was constructed out of transparent machined acrylic, designed to minimize occlusion of the desk surface...

Código	Palavra-chave	Projeto	Palavra-chave em contexto
SP. 9	surface	metaDESK	By rotating or translating the Dome object across the desk's surface, both the 2D desk-view and 3D lens-view are correspondingly transformed.
SP. 10	surface	metaDESK	... the physical space of the Dome object; the 2D graphical space of the desk's surface; and the 3D graphical space of the active lens.
SP. 11	surface	metaDESK	The user next takes a second physical icon from the holding tray, this time representing the Media Lab building, and places it onto the surface of the desk.
SP. 12	surface	metaDESK	... the "passive lens," a wood-framed transparent surface that functions as an independent display when augmented by the back-projected desk.
SP. 13	surface	metaDESK	Since passive lens devices are passive transparent surfaces, many variously afforded lenses might be used simultaneously with no additional active display resources (i.e., additional computer-driven screens).
SP. 14	surface	metaDESK	... providing an interesting representational contrast with the hand-rendered map and polygonal 3D model of the desk and active-lens surfaces.
SP. 15	surface	metaDESK	The largest component is the desk itself, a back-projected near-horizontal graphical surface used to display 2D geographical information within the Tangible Geospace prototype.
SP. 16	surface	metaDESK	In addition, several passive physical objects are manipulated by the user on the surface of the desk.
SP. 17	surface	metaDESK	It uses a three-tube projector to display computer graphics via two internal mirrors onto a plexiglass diffuser surface, which forms the near-horizontal display surface of the desk.
SP. 18	surface	metaDESK	While a completely horizontal display surface is desirable for supporting physical objects without slippage...
SP. 19	surface	metaDESK	We cover the display surface with a clear plastic film that minimizes object slippage.
SP. 20	surface	metaDESK	...the distance of the virtual camera from the active lens surface follows an exponential curve with empirically-derived coefficients.
SP. 21	surface	metaDESK	Early iterations of the passive lens were tested both with a plexiglass "lens" and with an empty frame without interior surface.
SP. 22	surface	metaDESK	However, the intention with the passive lens was to give the illusion of an independent display surface, i.e. a separate screen.
SP. 23	surface	metaDESK	... the fiber-optic cluster material succeeded in visually simulating an independent display surface.
SP. 24	surface	metaDESK	The desk is augmented with two cameras mounted inside its chassis aimed at the back-projected diffuser display surface from underneath.
SP. 25	surface	metaDESK	...realizes a modest user-privacy gain in that objects more than ~10cm above the desk surface are invisible to the cameras because of the diffuser coating.
SP. 26	surface	metaDESK	We are interested in new applications using combined 2D and 3D graphical surfaces for information without native visual or physical form.
SP. 27	surface	metaDESK	... a user interface platform supporting physical interaction with digital information through the manipulation of physical objects, instruments, and surfaces.
SP. 28	surface	metaDESK	... objects and instruments manipulated upon a near-horizontal display surface internally monitored with infrared computer vision.
SP. 29	surface	metaDESK	This interface surface is complemented with the arm-mounted "active lens" flat-panel display ...
SP. 30	surface	PSyBench	The objects have magnetic bases so that they can be moved using an electromagnet placed on a 2-axis positioning mechanism under the surface.
SP. 31	surface	PSyBench	...all users, be they local or remote, essentially interact with the workspace in the same way: by manipulating physical objects on the augmented table's surface.

Código	Palavra-chave	Projeto	Palavra-chave em contexto
SP. 32	surface	inTouch	Three was chosen as a compromise between the higher spatial resolution provided by more rollers and a greater surface area (on each roller) to “grab” and interact with possible with fewer larger diameter rollers.
SP. 33	surface	musicBottles	The table houses three Color Kinetics lights, and the stage area acts as a rear-projection surface for the display of dynamic light compositions that accompany the music.
SP. 34	surface	CurlyBot	...curlybot is an autonomous two-wheeled vehicle with embedded electronics that can record how it has been moved on any flat surface and then play back that motion accurately and repeatedly.
SP. 35	surface	Urp	...the application is based allows physical architectural models placed on an ordinary table surface to cast shadows accurate for arbitrary times of day;
SP. 36	surface	Urp	...adapting the shadow-technique (light sources positioned above the models) for reflections requires plac- ing small patches of reflective material the models’ various surfaces...
SP. 37	surface	Urp	...the wholesale transformation of architectural space – to make of each surface an information-display-and-interaction structure.
SP. 38	surface	Urp	...known objects use an optical tagging scheme in which small colored dots are applied to the surface of each physical implement.
SP. 39	surface	Urp	...in part because of the angle-doubling that occurs at the bounce surface, and in part because not all of the components of the reflection are necessarily in contact with the object itself.
SP. 40	surface	Urp	... small ‘polygons of light’ can be thrown huge distances away from the building that generates them, depending on the angle and orientation of the responsible surface.
SP. 41	surface	Urp	The result is a real-time simulation in which fluid appears to flow from right to left across a table surface...
SP. 42	surface	Sensetable	...electromagnetically tracks the positions and orientations of multiple wireless objects on a tabletop display surface.
SP. 43	surface	Sensetable	The notion of an interactive display surface that is able to sense the positions of objects on top of it has been discussed in the HCI literature for many years.
SP. 44	surface	Sensetable	To support our research in interactive tabletop surfaces, we decided to develop a new platform, called Sensetable...
SP. 45	surface	Sensetable	...provide accurate, low-latency wireless tracking of 6-10 objects on a flat surface.
SP. 46	surface	Sensetable	The I/O bulb system demonstrated the use of an interactive surface for urban planning.
SP. 47	surface	Sensetable	...a pair of modified commercially available Wacom Intuous™ sensing tablets that are placed next to each other to form a 52cm x 77cm sensing surface.
SP. 48	surface	Sensetable	As well, the mice used with these tablets each have a 32 bit serial number, which is useful for identifying mice when they move from one sensing surface to another.
SP. 49	surface	Sensetable	The pucks have two sockets inside of a crescent shaped recess on their top surfaces...
SP. 50	surface	Sensetable	One receives the data from the sensing surface and displays graphics onto the sensing surface in response.
SP. 51	surface	Sensetable	One receives the data from the sensing surface and displays graphics onto the sensing surface in response.
SP. 52	surface	Sensetable	A second computer drives two vertical displays to the rear of the sensing surface...
SP. 53	surface	Sensetable	...Graphical representations of digital information are projected onto the tabletop sensing surface.
SP. 54	surface	Sensetable	Sharing information between the tabletop sensing surface and a traditional display screen.
SP. 55	surface	Sensetable	...unbind a puck from its associated digital information by picking the puck up off of the sensing surface and placing it down on top of some other digital item on the surface.

Código	Palavra-chave	Projeto	Palavra-chave em contexto
SP. 56	surface	Sensetable	...unbind a puck from its associated digital information by picking the puck up off of the sensing surface and placing it down on top of some other digital item on the surface.
SP. 57	surface	Sensetable	...our current hardware prototype has difficulty differentiating the act of lifting a puck off of the sensing surface from a puck switching itself on and off as part of the time-sharing...
SP. 58	surface	Sensetable	Our second generation prototype of the system includes the ability to detect when objects have been lifted off of the sensing surface...
SP. 59	surface	Sensetable	First, they wanted the information about the changes caused by manipulating the dials to be displayed on the sensing surface in addition to being displayed on a screen behind the surface.
SP. 60	surface	Sensetable	First, they wanted the information about the changes caused by manipulating the dials to be displayed on the sensing surface in addition to being displayed on a screen behind the surface.
SP. 61	surface	Sensetable	...one could use the dials by focusing just on the table surface itself, rather than having to divide one's attention between the input on the sensing surface and the output of a rear display screen.
SP. 62	surface	Sensetable	...one could use the dials by focusing just on the table surface itself, rather than having to divide one's attention between the input on the sensing surface and the output of a rear display screen.
SP. 63	surface	Sensetable	At times, users may wish to interact with more data at one time than can be legibly displayed on the sensing surface.
SP. 64	surface	Sensetable	...one can show different parts of the model in different levels of detail at the same time on the sensing surface.
SP. 65	surface	Sensetable	...a user might want to share data between the tabletop interaction surface and an on-screen display in order to use tangible and WIMP interaction techniques together.
SP. 66	surface	Sensetable	More recent augmented surfaces work adds the notion of a spatially continuous connection between the screens of portable computers and nearby tabletops and wall surfaces.
SP. 67	surface	Sensetable	More recent augmented surfaces work adds the notion of a spatially continuous connection between the screens of portable computers and nearby tabletops and wall surfaces.
SP. 68	surface	Sensetable	A flat panel display is aligned with the left side of the rear of the sensing surface, so that the display area of the flat panel begins where the display and sensing surface of the tabletop ends.
SP. 69	surface	Sensetable	A flat panel display is aligned with the left side of the rear of the sensing surface, so that the display area of the flat panel begins where the display and sensing surface of the tabletop ends.
SP. 70	surface	Sensetable	Directly below each of these boxes is a corresponding box projected on the sensing surface itself.
SP. 71	surface	Sensetable	By adjusting the layout of our graphs on the sensing surface, we often removed some of this information.
SP. 72	surface	Sensetable	The user can move one of these subgraphs from the vertical display to the tabletop sensing surface using the data sharing technique described in the "Interaction Techniques" section.
SP. 73	surface	Sensetable	We have presented Sensetable, a robust platform for tracking multiple objects wirelessly on a flat surface with high accuracy and low latency.
SP. 74	surface	Sensetable	The new surface is constructed from 25 cm square sensing boards, which can be tiled to form sensing areas of varying size and shape.
SP. 75	surface	Sensetable	...the number of objects which can be tracked at one time on the new board will be the number of objects which can physically fit on the surface.
SP. 76	surface	Sensetable	One example is the use of a fold down display surface attached to the side of a puck.

Código	Palavra-chave	Projeto	Palavra-chave em contexto
SP. 77	surface	Sensetable	If the puck can sense when the display surface is folded open, the position and orientation of the puck on the sensing surface can be used to project extra information about the puck onto the surface.
SP. 78	surface	Sensetable	If the puck can sense when the display surface is folded open, the position and orientation of the puck on the sensing surface can be used to project extra information about the puck onto the surface.
SP. 79	surface	Sensetable	If the puck can sense when the display surface is folded open, the position and orientation of the puck on the sensing surface can be used to project extra information about the puck onto the surface.
SP. 80	surface	Actuated Workbench	Interactive tabletop surfaces are a promising avenue of research in Tangible User Interfaces.
SP. 81	surface	Actuated Workbench	...track the position and movement of objects on a flat surface and respond to users' physical input with graphical output.
SP. 82	surface	Actuated Workbench	With the computer system unable to move the objects on the table surface, it cannot undo physical input, correct physical inconsistencies in the layouts of the objects, or guide the user in the physical manipulation of the objects
SP. 83	surface	Actuated Workbench	The Actuated Workbench provides a hardware and software infrastructure for a computer to smoothly move objects on a table surface in two dimensions.
SP. 84	surface	Actuated Workbench	Finally, our ideal system would be silent, so as not to unintentionally distract the user when an object is moved on the surface.
SP. 85	surface	Actuated Workbench	...in order to provide the strong attractive forces needed to drag the 14g (0.5oz) pucks around on the Active Workbench's acrylic surface.
SP. 86	surface	Actuated Workbench	A felt pad is attached to the bottom of each puck, providing the necessary kinetic friction to keep the object from sliding around uncontrollably on the table's surface.
SP. 87	surface	Actuated Workbench	...results in the permanent magnet being about 1.26cm (1/2") from the surface of the table...
SP. 88	surface	Actuated Workbench	This attraction increases friction on the object, which affects the puck's ability to slide on the surface.
SP. 89	surface	Actuated Workbench	In general, we observed that static friction (the friction between the object and the surface when the object is at rest) inhibited smooth motion of the pucks...
SP. 90	surface	Actuated Workbench	The current design of our pucks is somewhat limited in that we cannot control their rotation on the surface.
SP. 91	surface	Actuated Workbench	Electromagnetic radio frequency sensing technology is evolving rapidly to provide robust, low-latency object tracking on table surfaces.
SP. 92	surface	Actuated Workbench	...it is not so useful for recreating the smooth motions with which a user moves objects on an interactive workbench's surface.
SP. 93	surface	Actuated Workbench	A single puck on the surface of the Actuated Workbench is subject to gravitational force, frictional force, the magnetic forces of attraction...
SP. 94	surface	Actuated Workbench	The computer-controlled configuration of objects on a flat surface has been studied in both the HCI domain and in the realm of industrial mechanics.
SP. 95	surface	Actuated Workbench	The Universal Planar Manipulator (UPM) uses the horizontal vibration of a flat surface to move multiple objects at a time.
SP. 96	surface	Actuated Workbench	Complex movements of specific objects on the surface are achieved using interference patterns of the vibration waves as they propagate across the surface.
SP. 97	surface	Actuated Workbench	Complex movements of specific objects on the surface are achieved using interference patterns of the vibration waves as they propagate across the surface.
SP. 98	surface	Actuated Workbench	Second, the mechanism for vibrating the surface occupies space around the edges, preventing the easy tiling of multiple surfaces.



Código	Palavra-chave	Projeto	Palavra-chave em contexto
SP. 99	surface	Actuated Workbench	Second, the mechanism for vibrating the surface occupies space around the edges, preventing the easy tiling of multiple surfaces.
SP. 100	surface	Actuated Workbench	Third, the system is noisy due to the mechanism needed to vibrate the flat surface and the sound of the vibrating objects.
SP. 101	surface	Actuated Workbench	This actuation method presents a clever solution to the problem of friction by doing away with the friction between two flat surfaces
SP. 102	surface	Actuated Workbench	Moreover, the surface upon which the objects rest is neither flat nor continuous...
SP. 103	surface	Actuated Workbench	...we plan to tile four to six of these arrays to form an actuation surface 13" to 19", which should be large enough for use with most interactive workbench interface systems.
SP. 104	surface	Actuated Workbench	The integration of these two technologies will require careful placement of the magnets in relation to the tracking surface.
SP. 105	surface	Actuated Workbench	Another tracking possibility might use Hall-effect sensors under the table's surface to detect the permanent magnet in the puck.
SP. 106	surface	Actuated Workbench	...forces could be used to provide greater control over the friction between the pucks and the table surface.
SP. 107	surface	Actuated Workbench	The value of $\mu_k$ can range from 0.05 to 1.5, depending on the choice of materials for the puck bottom and the table surface.
SP. 108	surface	Illuminating Clay	The results of this analysis are projected back into the workspace and registered with the surfaces of the model.
SP. 109	surface	Illuminating Clay	He points out that automobile designers work extensively with physical, tape and clay models, even while they have access to sophisticated curved-surface modelers.
SP. 110	surface	Illuminating Clay	Agrawala et al have looked into methods for painting directly on the surfaces of complex 3D geometries
SP. 111	surface	Illuminating Clay	This configuration ensures that all the surfaces that are visible to the scanner can also be projected upon.
SP. 112	surface	Illuminating Clay	We use a standard Mitsubishi 640 x 480 LCD projector to cast the results of landscape analysis functions back onto the surfaces of the physical model.
SP. 113	surface	Illuminating Clay	The worktable comprises of a smooth white surface suitable for projection and a platform onto which a model of a specific site is placed.
SP. 114	surface	Illuminating Clay	The remaining two edges of the work surface are used to project cross sections of the model enhancing the users' 3-dimensional understanding of the terrain.
SP. 115	surface	Illuminating Clay	The matte white finish is highly suitable as a projection surface and does not leave a residue on the user's hands.
SP. 116	surface	Illuminating Clay	The results of this function are then 'cast' back onto the surfaces of the model.
SP. 117	surface	Illuminating Clay	In order to calibrate the system the unprocessed DEM is projected onto the surface of the model and scaled in order that each scanned point on the model corresponds with each projected pixel.
SP. 118	surface	Illuminating Clay	The calculation of slope and curvature, involves processing the DEM using two Sobel filters to determine the x and y derivatives of the topographic surface...
SP. 119	surface	Illuminating Clay	We have shown that the SCANcast mode offers the ability to display information on the surface of a 3 dimensional model.
SP. 120	surface	Illuminating Clay	However, SCANcast does not allow 3-dimensional information, relating to conditions above the surface of the model, to be displayed.
SP. 121	surface	Illuminating Clay	If the designer of a wind farm wishes to know the precise wind speed at a point 3 meters above the surface of the landscape they need to insert surface for projection 3 meters above the surface of the model topography.

Código	Palavra-chave	Projeto	Palavra-chave em contexto
SP. 122	surface	Illuminating Clay	If the designer of a wind farm wishes to know the precise wind speed at a point 3 meters above the surface of the landscape they need to insert surface for projection 3 meters above the surface of the model topography.
SP. 123	surface	Illuminating Clay	If the designer of a wind farm wishes to know the precise wind speed at a point 3 meters above the surface of the landscape they need to insert surface for projection 3 meters above the surface of the model topography.
SP. 124	surface	Illuminating Clay	The user is then free to add surfaces for projection at will, and to 'cut' the space above the model without affecting the simulation results.
SP. 125	surface	Illuminating Clay	Any surface can be used to make this cut, whether it is the surface of a stiff sheet of translucent plastic or cardboard or indeed a more complex form such as a sphere or even the user's hand.
SP. 126	surface	Illuminating Clay	As material is removed from the model the color of the surface becomes progressively bluer until the surface of the physical model and digital model are the same.
SP. 127	surface	Illuminating Clay	As material is removed from the model the color of the surface becomes progressively bluer until the surface of the physical model and digital model are the same.
SP. 128	surface	Illuminating Clay	...Illuminating Clay offers a new contribution, by using the surface geometry of the model itself to act as the input and output juncture.
SP. 129	surface	Illuminating Clay	While being greatly limited by issues of occlusion the approach of projecting directly onto the surface of a 3-dimensional model...
SP. 130	surface	Illuminating Clay	Our approach makes no distinction between one object and another or even between the work surface and the model itself.
SP. 131	surface	Sandscape	Automobile designers work extensively with physical, tape and clay models, even if they have access to sophisticated curved-surface modellers.
SP. 132	surface	Sandscape	The results of this analysis are projected back into the workspace and registered with the surfaces of the model.
SP. 133	surface	Sandscape	Agrawala et al have developed methods for painting directly on the surfaces of complex 3-D geometries...
SP. 134	surface	Sandscape	Illuminating Clay uses a commercially available triangulation based laser scanner (Minolta Vivid-900TM) to capture the surface geometry of the physical clay model.
SP. 135	surface	Sandscape	This laser scanner is calibrated with a video projector, in order to ensure that the spatial co-ordinates of the surface of the model correspond precisely to the projected image co-ordinates.
SP. 136	surface	Sandscape	The scanner/projector pair is housed inside an aluminum casing at a height of approximately 2 m above the surface of the modelling material.
SP. 137	surface	Sandscape	In order to capture changes in the surface geometry of the modelling material in real time, it was necessary to modify the scanner controls using the Minolta Software Development Kit (SDK).
SP. 138	surface	Sandscape	...320 × 240 point values are scanned every 1.2 sec resulting in a near-real-time surface capture.
SP. 139	surface	Sandscape	A monochrome infra-red camera is mounted 2 m above the surface of the beads and captures the intensity of light passing through the volume.
SP. 140	surface	Sandscape	The intensity of transmitted light is a function of the depth of the beads and a look-up table can be used to convert surface radiance values into surface elevation values.
SP. 141	surface	Sandscape	The intensity of transmitted light is a function of the depth of the beads and a look-up table can be used to convert surface radiance values into surface elevation values.
SP. 142	surface	Sandscape	...the intensity at the top surface can vary greatly and sometimes exceed the dynamic range of the video camera.

Código	Palavra-chave	Projeto	Palavra-chave em contexto
SP. 143	surface	Sandscape	For example, placing a digital icon on the landscape surface by dragging the mouse prompts the numerical value of the simulation at that location to be shown
SP. 144	surface	Sandscape	The perspective view locations on the surface of the table and allow for the tracking of the Corian blocks.
SP. 145	surface	Sandscape	Fibre optics transfer light from the center cavity to the perimeter of the table and emit IR though six distinct locations on the surface of the table.
SP. 146	surface	Sandscape	In order to calibrate the system the unprocessed DEM is projected on to the surface of the model and scaled in order that each scanned point on the model corresponds with each projected pixel.
SP. 147	surface	Sandscape	Illuminating Clay can operate on almost all projectable surfaces and requires no dedicated worktable.
SP. 148	surface	Sandscape	The calculation of slope and curvature involves processing the DEM using two Sobel filters to determine the x and y derivatives of the topographic surface.
SP. 149	surface	Sandscape	While tracked physical models interfaced with a computer are not a novelty, we believe that Illuminating Clay and SandScape offer a new contribution, by using the continuous surface geometry of the model itself to act as the input/output mechanism.
SP. 150	surface	Sandscape	A DEM is generated in near-real-time according to the changing geometries of a clay or sand surface, and used to feed computational simulations.
SP. 151	surface	Sandscape	Illuminating Clay and SandScape seem to open a new perspective not only on GIS but also on TUIs by introducing the ‘Continuous TUIs’ category, which uses the 3-D surface of a continuous workspace as input and output.
SP. 152	surface	PICO	The interface is based on a tabletop interaction surface that can sense and move small objects on top of it.
SP. 153	surface	PICO	Fred Brooks et al. used a 6 degree-of-freedom haptic display together with visual display to help chemists explore and understand how drugs “dock” onto the surfaces of proteins.
SP. 154	surface	PICO	Several researchers have explored this idea of physical motion on a tabletop surface as part of a user interface.
SP. 155	surface	PICO	Actuated Workbench uses anti-aliasing and PID control algorithms to provide very smooth motion on the tabletop surface.
SP. 156	surface	PICO	One important result of this simple design is that the control system is robust in the face of mechanical obstructions on the interaction surface.
SP. 157	surface	PICO	As a result, for these conditions a videocamera was pointed at the interaction surface such that the user’s hand motions could later be analyzed.
SP. 158	surface	Relief	Relief is an actuated tabletop display, which is able to render and animate three-dimensional shapes with a malleable surface.
SP. 159	surface	Relief	The tabletop surface is actuated by an array of 120 motorized pins, which are controlled with a low-cost, scalable platform built upon open-source hardware and software tools.
SP. 160	surface	Relief	The display is both able to render shapes and sense user input through a malleable surface, which is actuated by an array of electric slide potentiometers.
SP. 161	surface	Relief	A well-known example of a shape display is FEELEX by Iwata et al., where 36 motorized pins actuate the shape of a soft surface, onto which graphics are projected.
SP. 162	surface	Relief	The pins are spaced 1.5 inches apart from each other and can protrude 5 inches from the table surface.
SP. 163	surface	Relief	Figure 2 depicts the display rendering a 3D model of a landscape, while the landscape texture is projected onto a Lycra surface covering the pins.
SP. 164	surface	Recompose	In this paper we present Recompose, a new system for manipulation of an actuated surface.

Código	Palavra-chave	Projeto	Palavra-chave em contexto
SP. 165	surface	Recompose	By collectively utilizing the body as a tool for direct manipulation alongside gestural input for functional manipulation, we show how a user is afforded unprecedented control over an actuated surface.
SP. 166	surface	Recompose	Recompose complements the highly precise, yet concentrated affordance of direct manipulation with a set of gestures allowing functional manipulation of an actuated surface.
SP. 167	surface	Recompose	However, these interfaces could not support precise sensing of the surface deformation and where not utilized for CAD modeling.
SP. 168	surface	Recompose	...inspired by the work of Hilliges et al., where a Microsoft surface table is combined with a depth camera for additional input.
SP. 169	surface	Recompose	Building upon this system, we have furthered the design by placing a depth camera above the tabletop surface.
SP. 170	surface	Recompose	A grammar of gestures has been implemented to explore basic functions used to interact with an actuated surface.
SP. 171	surface	Recompose	Initial explorations have found that the most fundamental set of gestures includes: selection of a subset of the surface, translation of the selection, rotation of the selection, and scaling of the selection.
SP. 172	surface	Recompose	In order to select a subset of the surface the user forms two parallel vertical planes with their hands.
SP. 173	surface	Recompose	After reaching the desired height and position the user can release the pinch gesture, saving surface state, and resetting the interaction state back to selection mode.
SP. 174	surface	Recompose	Direct manipulation of an actuated surface allows us to precisely affect the material world, where the user is guided throughout the interaction by natural haptic feedback
SP. 175	surface	Recompose	However, direct manipulation is incapable of affecting large areas of a surface due to constraints of the human body.
SP. 176	surface	Recompose	During development we encountered issues while translating common design techniques from a planar display to an actuated surface.
SP. 177	surface	Recompose	A full-scale timeline of all surface manipulation captured during a session allowing for time reversal, state saving, and undo type functions.
SP. 178	surface	Recompose	In regards to the mechanical system, we intend to pursue both higher fidelity gesture recognition coupled with higher resolution actuated surfaces to allow for a greater range of expression and interpretation.
SP. 179	surface	Recompose	In this paper we present Recompose, an interaction framework for direct and gestural manipulation of an actuated surface.
SP. 180	surface	Recompose	We intuitively use gestures to express intent and desire, and if the surfaces around us could better understand such notions then digital design could be a more transparent and seamless experience.
SP. 181	surface	ZeroN	Users are invited to place or move the ZeroN object just as they can place objects on surfaces
SP. 182	surface	ZeroN	This limitation might not appear to be a constraint for many tabletop interfaces, when content is mapped to surface components, but we argue that there are exciting possibilities enabled by supporting true 3D manipulation.
SP. 183	surface	ZeroN	There has been some movement in this direction already; researchers are starting to explore interactions with three-dimensional content using space above the tabletop surfaces.
SP. 184	surface	ZeroN	In these scenarios input can be sensed in the 3D physical space, but the objects and rendered graphics are still bound to the surfaces.
SP. 185	surface	ZeroN	At its core, our goal is to allow users to take physical components of tabletop tangible interfaces off the surface and place them in the air.

Código	Palavra-chave	Projeto	Palavra-chave em contexto
SP. 186	surface	ZeroN	In Actuated Workbench, an array of computer-controlled electromagnets actuates physical objects on the surface, which represent the dynamic status of computation.
SP. 187	surface	ZeroN	One approach to the transition of 2D modalities to 3D has been using deformable surfaces as input and output.
SP. 188	surface	ZeroN	To actuate deformable surfaces, Lumen and FEELEX employ an array of motorized sticks that can be raised.
SP. 189	surface	ZeroN	More importantly, because the objects are physically tethered, it is difficult for users to reach under or above the deformable surface in the interactive space.
SP. 190	surface	ZeroN	Hilliges and et al. show that 3D mid-air input can be used to manipulate virtual objects on a tabletop surface using the second-light infrastructure.
SP. 191	surface	ZeroN	Our paper explores this novel design space of tangible interaction in the mid-air space above the surface.
SP. 192	surface	ZeroN	Graphical images or icons may be projected upon the white surface of ZeroN levitating, such as a camera or the pattern of a planet.
SP. 193	surface	ZeroN	We have developed a 3D, tangible interaction language that closely resembles how people interact with physical objects on a 2D surface...
SP. 194	surface	ZeroN	Users can attach ZeroN to a digital item projected on the tabletop surface on the ground, just by moving the ZeroN close to the digital item to be bind with.
SP. 195	surface	ZeroN	One of the challenges is to provide users with a semantic link between the levitated object and tabletop tangible interfaces on the 2D surface.
SP. 196	surface	ZeroN	We developed an application for controlling external architectural lighting in which users can grab and place a Sun in the air to control the digital shadow cast by physical models on the tabletop surface.
SP. 197	surface	ZeroN	Attaching ZeroN to the camera icon displayed on the surface turns the sun into a camera object.
SP. 198	surface	ZeroN	Raising tabletop tangible interfaces to 3D space above the surface opens up many opportunities and leaves many interaction design challenges.
SP. 199	surface	JammingUI	ClaytricSurface by Matoba et al. combines a malleable tabletop jamming surface with a ceiling-mounted depth-sensing camera and projector as a sculpting interface.
SP. 200	surface	JammingUI	The malleable surface contains a pneumatic jamming apparatus, which allows for variable stiffness control.
SP. 201	surface	JammingUI	Granular particles can be combined with discrete element matrices as a hybrid approach to achieve smoother, higher-dimensional surfaces with variable stiffness.
SP. 202	surface	JammingUI	It is often desirable to sense users' freeform deformations of malleable devices, including 3D shapes, as well as interaction on and above surfaces.
SP. 203	surface	JammingUI	Sensing proximity and touch allows 2D and 3D non-planar surface manipulations...
SP. 204	surface	JammingUI	Glass beads provide a good balance of control and tactile stiffness response due to their smooth surfaces and low inter-particle friction.
SP. 205	surface	JammingUI	This device enables the use of different optical techniques for surface reconstruction, such as shape from shading, photometric stereo, embedded tracking markers in the skin, structured lighting, or other custom solutions.
SP. 206	surface	JammingUI	We use silver-plated 76% nylon, 24% elastic fiber fabric, which has a low surface resistivity, and can be stretched up to twice its length.
SP. 207	surface	JammingUI	Conductive fabric strips (9→1 cm <sup>2</sup> each) are embedded in the flexible skin as receiving electrodes, while strips of copper tape (also 9→1 cm <sup>2</sup> each) on the opposing, bottom surface act as transmitting electrodes, as shown in Figure 9.
SP. 208	surface	JammingUI	he model is shown both on a separate display and through projected graphics on the malleable surface for direct feedback

Código	Palavra-chave	Projeto	Palavra-chave em contexto
SP. 209	surface	JammingUI	The sensing and visible projection is integrated beneath the surface to avoid occlusions from user interactions.
SP. 210	surface	JammingUI	Users can control the stiffness of the malleable surface using a potentiometer.
SP. 211	surface	JammingUI	In order to investigate malleable interaction and haptic feedback in the context of mobile devices, we created a jamming input device mounted on the back surface of a tablet...
SP. 212	surface	JammingUI	The tablet's rear interface allows users to navigate content on a tablet display by pressing into its malleable surface.
SP. 213	surface	JammingUI	Tactile experience, surface quality and malleability benefit from low-friction particles and thin, elastic membranes.
SP. 214	surface	inFORM	The Actuated Workbench uses electromagnetism for 2D movement of tracked tangibles on an interactive surface...
SP. 215	surface	inFORM	Other techniques for moving objects on a 2D surface include vibration and robotics.
SP. 216	surface	inFORM	Mad- gets also provide affordances dynamically, by moving them around a surface or mechanically raising or locking elements.
SP. 217	surface	inFORM	The combination of dynamic surface topologies, actuated control of passive tangible objects, user sensing, and object tracking, provides a rich set of capabilities for dynamically controlled perceptible affordances that can optimize user guidance and interaction.
SP. 218	surface	inFORM	Users activate a button by touching it or by pushing it into the surface, which is registered as a binary input.
SP. 219	surface	inFORM	Touch surfaces are created using multiple pins, which are aligned to form surfaces.
SP. 220	surface	inFORM	Touch surfaces are created using multiple pins, which are aligned to form surfaces.
SP. 221	surface	inFORM	These surfaces, which can be non-planar, map each touch point to two dimensions.
SP. 222	surface	inFORM	Two flat surfaces might appear the same, and both afford touching, but once the user touches their surface, a stiff surface affords touch interaction, where a more compliant surface affords pressing.
SP. 223	surface	inFORM	Two flat surfaces might appear the same, and both afford touching, but once the user touches their surface, a stiff surface affords touch interaction, where a more compliant surface affords pressing.
SP. 224	surface	inFORM	Two flat surfaces might appear the same, and both afford touching, but once the user touches their surface, a stiff surface affords touch interaction, where a more compliant surface affords pressing.
SP. 225	surface	inFORM	Two flat surfaces might appear the same, and both afford touching, but once the user touches their surface, a stiff surface affords touch interaction, where a more compliant surface affords pressing.
SP. 226	surface	inFORM	The surface geometry can be changed to make it easier or harder for the user to move tokens in a certain direction.
SP. 227	surface	inFORM	Other factors to consider include the mass of the object, the force of the motors, and the friction between the shape display surface and the passive object.
SP. 228	surface	inFORM	This can be used, for example, to orient an object's surface towards a user.
SP. 229	surface	inFORM	In addition to lifting and tilting, objects can be translated on the X-Y surface through three techniques.
SP. 230	surface	inFORM	Firstly, objects can be lifted and caused to slide or roll down an inclined plane rendered by the surface, essentially using gravity to cause it to move.
SP. 231	surface	inFORM	Thirdly, tilt can be used for controlled tumbling of objects about the X- or Y-axis, by alternating tilting and catching, to move the object on the surface.
SP. 232	surface	inFORM	Objects can also be rotated about the surface's Z-axis through similar techniques as used for X-Y translation.

Código	Palavra-chave	Projeto	Palavra-chave em contexto
SP. 233	surface	inFORM	However, a simple surface feature to allow locking an object at an anchor point could allow for rotation through the aforementioned methods of pushing-induced sliding.
SP. 234	surface	inFORM	Currently, we are able to launch a 7 g ball with 20 mm diameter, approximately 80 mm above the maximum pin height of the surface.
SP. 235	surface	inFORM	The constraints defined by the shape display surface could also be user defined, for instance, by deforming the shapes directly with bare hands.
SP. 236	surface	inFORM	Therefore, we propose to complement them with passive physical tokens that enable these interactions, while they can also be constrained and actuated by the display surface shape.
SP. 237	surface	inFORM	The bristles of the brush move smoothly over the shape display surface, while being optically tracked by the system.
SP. 238	surface	inFORM	Its iconic form, sketched by Durrell Bishop, is a continuous surface with a raised hill and a hole in it.
SP. 239	surface	inFORM	The dynamic capabilities of inFORM could be used to render physical UI elements on-demand, for example, by having physical buttons and touch elements emerge when a tablet is placed on the surface.
SP. 240	surface	inFORM	The pins have a 9.525 mm <sup>2</sup> foot- print, with 3.175 mm inter-pin spacing, and can extend up to 100 mm from the surface.
SP. 241	surface	inFORM	Different shape primitive classes, or by directly writing data. The height map is then sent to the microcontrollers. Similarly, all 900 pin heights can be received over the RS485 bus, and used to track user's surface deformations as input.
SP. 242	surface	inFORM	Our current system uses an overhead depth camera to track users' hands and surface objects, as shown in Figure 10.
SP. 243	surface	inFORM	A Microsoft Kinect with a 640 x 480 pixel depth sensor is mounted 1200 mm above the surface and calibrated for extrinsic and intrinsic camera parameters.
SP. 244	surface	inFORM	We combine a static background image of the table surface with the surface's real-time height map to form a dynamic background image that is used for subtraction and segmentation.
SP. 245	surface	inFORM	We combine a static background image of the table surface with the surface's real-time height map to form a dynamic background image that is used for subtraction and segmentation.
SP. 246	surface	inFORM	Objects and finger positions are tracked at 2 mm resolution in the 2D surface plane, and at 10 mm in height.
SP. 247	surface	inFORM	Users tried the 3D Model Manipulation application and an example program to move passive objects on the surface autonomously.
SP. 248	surface	inFORM	We described two ways to move a ball on the shape display surface: pushing the ball or rolling it down a slope.
SP. 249	surface	inFORM	However, it is interesting to look at the larger space of possibilities for actuation and shape change: the user, the tool handle, tool, object, and physical surface must be considered.
SP. 250	surface	inFORM	In this work, we have focused on dynamically changing the physical surface, but these other areas and their combinations provide many interesting possibilities for new interactions.
SP. 251	surface	inFORM	For example, a tool can change shape as the interaction surfaces change shape as well.
SP. 252	surface	Sublimate	The first combines a optical see-through AR display, utilizing a stereo display, acrylic beam-splitter, and head tracking, with a shape display to co-locate 3D virtual graphics and a physical 2.5D surface.
SP. 253	surface	Sublimate	Yoshida et al. use an LCD and lens array to also provide parallax through retro-reflective projection off an arbitrarily shaped bottom surface.
SP. 254	surface	Sublimate	Toucheo demonstrates how these configurations can be combined with multi-touch surfaces and on-surface interaction techniques for 3D manipulations...

Código	Palavra-chave	Projeto	Palavra-chave em contexto
SP. 255	surface	Sublimate	Projection-based AR approaches have been explored in many projects to alter the visual properties of physical objects, particles, surfaces, or the user's body.
SP. 256	surface	Sublimate	One motivation for such systems is that they can modify the appearance of everyday objects without requiring an additional display surface.
SP. 257	surface	Sublimate	...FEELEX employs a flexible screen overlaid on the actuators for a continuous surface, and top-down projection for graphics.
SP. 258	surface	Sublimate	A virtually rendered surface can, e.g., materialize when a user approaches it with a finger, and upon proximity with a stylus tool, morph to a flattened shape to better support annotation.
SP. 259	surface	Sublimate	We propose a basic application that combines physical control for mesh manipulation with an overlaid graphical view of the resulting surface.
SP. 260	surface	Sublimate	The control points of a NURBS (Non-Uniform Rational Basis Spline) surface are represented by individual pins on the shape display.
SP. 261	surface	Sublimate	Grabbing and moving the pins up and down affects the resulting surface, which is displayed through co-located 3D graphics.
SP. 262	surface	Sublimate	The user can press a button to toggle the NURBS surface rendering from graphical to physical.
SP. 263	surface	Sublimate	In that case, the shape display outputs the geometry of the modeled surface instead of the control points and the user can feel the physical deformation.
SP. 264	surface	Sublimate	The location of the 3D graphics is not restricted to the surface of the cross section, as volumetric data underneath or above the surface can be rendered to get a better understanding of the data set.
SP. 265	surface	Sublimate	The location of the 3D graphics is not restricted to the surface of the cross section, as volumetric data underneath or above the surface can be rendered to get a better understanding of the data set.
SP. 266	surface	Sublimate	In this application scenario, the shape display renders physical terrain, while several tablet computers can be used to simultaneously interact and augment the physical surface.
SP. 267	surface	Sublimate	The shape display is augmented with projection onto the object surface to enhance appearance and provide graphical feedback when viewing the shape without the iPad.
SP. 268	surface	Sublimate	Multi-point, two-handed manipulation of a 3D surface is easier and faster than single-point haptic interaction.
SP. 269	surface	Sublimate	In the 3D surface manipulation task, the participant is asked to match a target surface with a co-located input surface.
SP. 270	surface	Sublimate	In the 3D surface manipulation task, the participant is asked to match a target surface with a co-located input surface.
SP. 271	surface	Sublimate	In the 3D surface manipulation task, the participant is asked to match a target surface with a co-located input surface.
SP. 272	surface	Sublimate	Both the input surface and the target surface are displayed as a wire-mesh rendering.
SP. 273	surface	Sublimate	Both the input surface and the target surface are displayed as a wire-mesh rendering.
SP. 274	surface	Sublimate	In the bimanual condition (Multi-push), participants could manipulate as many pins at once as they wanted, using their finger, palms or any surface of their two hands.
SP. 275	surface	Sublimate	Depth cameras could be an interesting alternative as they would enable the tracking of freehand input and potentially provide for denser surface geometry, as opposed to the current marker-based tracking.
SP. 276	surface	PneUI	Thus a range of technologies in HCI have been developed to enable soft and organic interfaces, including flexible sensing techniques, dynamic stiffness, texture and buttons on malleable surfaces, soft deformable surface output, and 2.5D shape display with elastic covers.



Código	Palavra-chave	Projeto	Palavra-chave em contexto
SP. 277	surface	PneUI	Thus a range of technologies in HCI have been developed to enable soft and organic interfaces, including flexible sensing techniques, dynamic stiffness, texture and buttons on malleable surfaces, soft deformable surface output, and 2.5D shape display with elastic covers.
SP. 278	surface	PneUI	Primitives of soft shape changing at both macro and micro scales, including curvature change of surfaces, unidirectional volume change of solid geometries, and dynamic texture change.
SP. 279	surface	PneUI	...1) conductive pads composited on structural layers for sensing shape output and gestural input using capacitive and electric field sensing; 2) liquid metal embedded in elastomeric air channels for sensing deformation of soft surfaces.
SP. 280	surface	PneUI	In contrast to other techniques for shape change, such as spatial arrangement of actuated modules [20], self-foldable chains, self-foldable surfaces, soft robotics often focuses on pneumatic actuation...
SP. 281	surface	PneUI	Shape memory alloy (SMA) based actuators have been used to bend surfaces.
SP. 282	surface	PneUI	...with a variety of different materials for creating soft and ridged buttons, and integrated multi-touch sensing on the surface through diffuse illumination, pressure sensing for input.
SP. 283	surface	PneUI	Granular jamming, which can also be controlled pneumatically, can provide malleable surface with adjustable stiffness, and allows for passive shape change.
SP. 284	surface	PneUI	A range of sensing techniques on soft surfaces has been explored in HCI, optical sensing and flexible capacitive sensing are among common approaches.
SP. 285	surface	PneUI	“Sensing through structure” has been introduced to sense the deformation of flexible surfaces and structures.
SP. 286	surface	PneUI	In Soft Robotics, sensing through the deformation of the surface itself is a unique approach afforded by the elastic nature of soft materials.
SP. 287	surface	PneUI	We categorize the achievable sensing modalities into: 1) sensing gestures on the surface, 2) gestures hovering over the surface, 3) gestures that deform the surface, and 4) air deforming the surface.
SP. 288	surface	PneUI	We categorize the achievable sensing modalities into: 1) sensing gestures on the surface, 2) gestures hovering over the surface, 3) gestures that deform the surface, and 4) air deforming the surface.
SP. 289	surface	PneUI	We categorize the achievable sensing modalities into: 1) sensing gestures on the surface, 2) gestures hovering over the surface, 3) gestures that deform the surface, and 4) air deforming the surface.
SP. 290	surface	PneUI	We categorize the achievable sensing modalities into: 1) sensing gestures on the surface, 2) gestures hovering over the surface, 3) gestures that deform the surface, and 4) air deforming the surface.
SP. 291	surface	PneUI	Further, the innate characteristics of soft interface could afford a wider variety of manipulations to deform the surface, such as pushing, stretching, bending, embracing, stroking and squeezing.
SP. 292	surface	PneUI	For example, Jamming particles can control surface stiffness to give haptic affordances or lock shapes in a certain state...
SP. 293	surface	PneUI	...and thermochromic liquid crystals can be injected into air channels of elastomer to change the color of surfaces.
SP. 294	surface	PneUI	The soft mechanical alphabet describes the combination of compression and elongation to generate curvatures at given points of a surface.
SP. 295	surface	PneUI	We introduce two types of composite materials to generate such surface curvatures, utilizing compression and elongation behaviors with inflatable airbags.

Código	Palavra-chave	Projeto	Palavra-chave em contexto
SP. 296	surface	PneUI	When inflated, the inner airbags function as actuators to generate elongation and force the surface to bend towards the opposite direction.
SP. 297	surface	PneUI	Low density creases enable sharper bends and by varying the location of crease, we can control the bending location on the surface.
SP. 298	surface	PneUI	Finally, through Figure 6g and 6h we demonstrate a variation of on-surface pattern cuts on thin pieces of wood instead of paper.
SP. 299	surface	PneUI	While inflated, the airbags behave like the biceps (the muscle to pull the arm up), and compresses itself to cause the surface to bend.
SP. 300	surface	PneUI	The inflation of nonelastic airbags happens on the same side as the surface bends towards.
SP. 301	surface	PneUI	Experiments indicate that muscle like nonelastic airbags have stronger bending force than aforementioned elastic airbags, and can bend thicker paper or surfaces made from thin wood or plastic.
SP. 302	surface	PneUI	In this case silicon serves three functions: sealing the origami structure for air actuation, coating the paper surface for enhancing material durability constraining elasticity of origami structure within a specific range.
SP. 303	surface	PneUI	Another approach to generate texture on soft surfaces is to composite flexible material with cut patterns.
SP. 304	surface	PneUI	We demonstrate that the same surface will deform from macro to micro level as air pressure is increased.
SP. 305	surface	PneUI	To sense input and output, we have explored different sensing techniques, including compositing electrodes to sense global structural change, and embedding fluid conductors to sense local surface deformation with high sensitivities.
SP. 306	surface	PneUI	Further, through the application of shape shifting lamp, we have also demonstrated the possibility of compositing rigid electrical components, such as surface mounted LEDs, within soft bodies.
SP. 307	surface	PneUI	Soft robotic engineers have shown how to construct elastic sensing surfaces by injecting conductive liquid metal (eGaIn) into inner channels of elastomer.
SP. 308	surface	PneUI	It can sense surface deformation through both direct manipulation and air actuation.
SP. 309	surface	PneUI	The surface will animate between flat and bending state when a call comes in.
SP. 310	surface	PneUI	The fabrication of the shape changing mobile is based on one type of the aforementioned primitives: curvature change on surfaces.
SP. 311	surface	PneUI	The construction of the lamp is inspired by one type of shape changing primitives: the curling behavior under curvature change on surfaces.
SP. 312	surface	PneUI	Before the casting process, surface mounted LEDs are soldered on top of flexible copper strips.
SP. 313	surface	PneUI	For example, Helium, or hot air can let inflated surfaces float in air or water.
SP. 314	surface	PneUI	For example, topological change, including creating holes on surfaces, can give interesting affordances for interaction.
SP. 315	surface	jamSheets	Organic User Interfaces (OUI) leverage the advantages of soft materials, which allow interfaces to be deformed and adapted to any non-planar surface.
SP. 316	surface	jamSheets	In the creation process of design and architecture, sheet materials, such as paper, have been frequently used for transforming flat surfaces into three-dimensional objects by cuts and folds.
SP. 317	surface	jamSheets	ClaytricSurface is another example of a pneumatic jamming tabletop interface, which enables optical shape sensing through a ceiling-mounted depth-sensing camera.

Código	Palavra-chave	Projeto	Palavra-chave em contexto
SP. 318	surface	jamSheets	By building on top of such existing jamming-interface research, we introduce a new technique, layer jamming, to design thin surface interfaces with tunable stiffness.
SP. 319	surface	jamSheets	It cannot be used to construct thin and light surfaces/walls with tunable stiffness.
SP. 320	surface	jamSheets	...n and $\mu$ represent the overlapped surface area, the pressure applied on the surface, the number of layers present, and friction coefficient of the thin layers respectively...
SP. 321	surface	jamSheets	Geometrical patterns cut into jamming flaps: Since the jamming stiffness depends on the contact surfaces of the flaps, we can vary the stiffness locally by cutting out the material based on a designed pattern.
SP. 322	surface	jamSheets	Combining jamming materials can not only vary the jamming stiffness within a certain thickness or weight limitation, but it can also maintain surface softness when jammed.
SP. 323	surface	jamSheets	For example, by adding a layer of soft felt to a stack of paper, a high resistive bending force can be achieved by the stack of paper, while softness of the felt remains on the surface of the composite.
SP. 324	surface	jamSheets	Mutual capacitive sensing is also explored as an approach to detect proximity between two folding surfaces.
SP. 325	surface	jamSheets	In the second scenario, the surface can transform from a shared display into a private working station.
SP. 326	surface	jamSheets	In one state, shared contents are displayed on a flat surface...
SP. 327	surface	jamSheets	By introducing air actuation, layer-jamming surfaces can be self-actuated and deformed when flexible, and jammed into a rigid configuration once it reaches the desired state.
SP. 328	surface	jamSheets	We attach two air bladders at the hinge of a bendable surface, which is a jamming bag by itself.
SP. 329	surface	jamSheets	The two air bladders function as actuators, which can compress and therefore bend the surface when it is flexible.
SP. 330	surface	jamSheets	Jamming the surface will maintain the actuated shapes.
SP. 331	surface	jamSheets	Compared to our existing composite sensing techniques, optic tracking can detect the 3D spatial change of the jamming surface.
SP. 332	surface	jamSheets	In previous work on particle-jamming user interfaces, malleability has been described as one advantage of deformable 2.5D surfaces or objects.
SP. 333	surface	jamSheets	In the future, there are two ways to design jamming surfaces that can be self-deformed and jammed in various ways.
SP. 334	surface	jamSheets	First, by placing multiple air actuators and inflating different combinations of them, the same surface can be deformed in different ways
SP. 335	surface	jamSheets	Second, by placing a single air actuator but multiple jamming bladders, we can tune the stiffness at different locations, so that the surface can be deformed differently.
SP. 336	surface	jamSheets	If combined with voice, gesture or external switch controls, the self-actuated surfaces can respond to multimodal inputs and transform accordingly.
SP. 337	surface	OptiElastic	We composite pairs of optical fibers into elastomer for touch sensing on deformable surfaces.
SP. 338	surface	OptiElastic	Using optical fibers for illumination and sensing is a widely explored domain in HCI: sensing and illumination cloth, touch sensing on rigid surfaces...
SP. 339	surface	OptiElastic	By embedding optical waveguides with their lengths perpendicular to the silicone surfaces, we can create elastic materials with pixelated displays.
SP. 340	surface	OptiElastic	This approach has been used for touch sensing on rigid surfaces.
SP. 341	surface	OptiElastic	To illuminate a certain pattern on an elastomeric surface, in addition to utilizing the aforementioned pixel approach, we can also design predefined patterns.
SP. 342	surface	LineFORM	However these explorations have mainly focused on shape changing surfaces, volumes, and actuated tabletop robots.

Código	Palavra-chave	Projeto	Palavra-chave em contexto
SP. 343	surface	LineFORM	Many different topologies for shape-changing interfaces have been explored ranging from actuated points, surfaces, solids and modular robots.
SP. 344	surface	LineFORM	Also, curves have the capability to represent not only 2D or 3D curves, but also a single continuous curve can be bent and shaped to form surfaces and solid-based shapes.
SP. 345	surface	LineFORM	Actuated curves can also transform into surfaces through a number of techniques...
SP. 346	surface	LineFORM	These surfaces can be touched and manipulated and afford different interactions than curves.
SP. 347	surface	LineFORM	Chains of actuators oriented with the same rotational axis can create only 2D planar surfaces, whereas chains of actuators with alternating orientations can create 3D surfaces.
SP. 348	surface	LineFORM	Chains of actuators oriented with the same rotational axis can create only 2D planar surfaces, whereas chains of actuators with alternating orientations can create 3D surfaces.
SP. 349	surface	LineFORM	It can have 2D or 3D touch input by transforming into surface or solid forms.
SP. 350	surface	LineFORM	Once the user peels off the device from the wrist, it transforms into flat rectangular surface by folding itself into tight serpentine curves and then the user can give touch input.
SP. 351	surface	bioLogic	While the endospore solution requires mixing with Polyisiline in order to be attached to latex surfaces, the hygromorphic bonds between natto cells and latex substrate behave as natural glue that can resist up to a 2 minute flush of water.
SP. 352	surface	bioLogic	Through combining the bending primitives across different dimensions, we can create a variety of responsive transformations including 1D linear transformation, 2D surface expansion and contraction, 2.5D texture change and 3D folding.
SP. 353	surface	bioLogic	Where S is a certain surface area, v is the machine flowrate.
SP. 354	surface	bioLogic	To allow the deposition to cover the whole surface area S...
SP. 355	surface	bioLogic	The way we create patterned deposition is through masking: laser cut mask with photo-mount spray is attached to the substrate surface before the atomizing process.
SP. 356	surface	bioLogic	Different techniques have their unique benefits: fast prototyping (electric motors), big force and compliant to malleable surfaces (pneumatic actuators), silent and flexible (shape memory alloy), phase transition (ferromagnetic fluids).
SP. 357	surface	UniMorph	Primitives of uniMorph shape-changing which includes curvature change of surfaces; controlled hinging and assembly of 3D structures; programming of neutral state of the material.
SP. 358	surface	UniMorph	A variety of sensing techniques on flexible surfaces have been explored in HCI.
SP. 359	surface	UniMorph	Finally, the Pyralux laminate allows for easy integration of surface mount components - which significantly expands the sensing capabilities of the uniMorph composite.
SP. 360	surface	UniMorph	While surfaces are already used for a wide variety of applications, the HCI field has an increasing interest in actuated three-dimensional structures built with origami techniques.
SP. 361	surface	UniMorph	The Pyralux in the uniMorph composite can be used to easily embed surface mount components.
SP. 362	surface	TRANSFORM	Furniture design typically focuses on the aesthetics of the surfaces of still objects.
SP. 363	surface	TRANSFORM	We also focused on the dramatic transformation from a static state into a dynamic machine. We begin with a quiet water surface and schools of swimming fish.

Código	Palavra-chave	Projeto	Palavra-chave em contexto
SP. 364	surface	TRANSFORM	This then transforms into two dynamic modes: an interactive mode responding to arm and hand movement and generating waves, and another pre-scripted mode telling a dynamic story illustrated through fluid surface movements.
SP. 365	surface	TRANSFORM	TRANSFORM is a platform based on actuator modules with 12 X 2 styrene pins covering an area of 305 X 50.8 mm, which extends up to 100 mm from the surface.
SP. 366	surface	TRANSFORM	The modules can be seamlessly combined to form a larger shape display surface.
SP. 367	surface	TRANSFORM	... and a wider top surface than the amount of pins actually produced (by splitting the pins).
SP. 368	surface	TRANSFORM	These shy creatures would appear and roam the TRANSFORM surface until someone approached the table.
SP. 369	surface	Kinetic Blocks	This interplay of the shape display with objects on its surface allows us to render otherwise inaccessible forms, like overhangs, and enables richer input and output.
SP. 370	surface	Kinetic Blocks	Since 2.5D shape displays cannot laterally push objects, we move a rectangular or cubical object across the surface by creating a ramp sloped at 45 degrees.
SP. 371	surface	Kinetic Blocks	Due to variations in the ramp surface, the blocks may start to tumble when moving at high speeds.
SP. 372	surface	Kinetic Blocks	Specifically, we considered a misalignment failure to occur when more than 20% of a block's bottom surface area protruded off the base block.
SP. 373	surface	ChainFORM	Modules are equipped with rich input and output capability: touch detection on multiple surfaces, angular detection, visual output, and motor actuation.
SP. 374	surface	ChainFORM	To extend the sensing and display capability of such shape changing interfaces, extra sensors or cameras and projectors have been installed for detecting human input and displaying information on the active surfaces.
SP. 375	surface	ChainFORM	The color of the surface of each module can be displayed with LEDs to provide visual feedback.
SP. 376	surface	ChainFORM	An array of 8 Neopixels Mini (Adafruit) was used for the LED display covering a single surface of a module.
SP. 377	surface	ChainFORM	The circuit board is designed to integrate six capacitive sensing surfaces...
SP. 378	surface	ChainFORM	....so that every surface of the module is capable of touch sensing.
SP. 379	surface	ChainFORM	For example, for CAD software, the chained interface can let users manipulate vector data tangibly as a line and form a touch surface as a color picker.
SP. 380	surface	ChainFORM	Although a lot of systems for shape changing flexible displays have been proposed, they mostly consist of rectangular surfaces that can create slight curves.
SP. 381	surface	ChainFORM	Utilizing the form factor of a line, this display can wrap around objects to change any surface into displays.
SP. 382	surface	ChainFORM	Similar to the multi-touch pen system presented in, the CAD function can be defined by the way users hold the grip utilizing the multiple touch sensing surfaces.
SP. 383	surface	ChainFORM	Also, there was only single surface of LED arrays, but having LEDs on every surface of the module would expand the display capability especially in 3D configurations.
SP. 384	surface	Cillia	This work presents a method for 3D printing hair-like structures on both flat and curved surfaces.
SP. 385	surface	Cillia	Inspired by how hair achieves those properties with its unique high aspect ratio structure, we are exploring ways of digitally designing and fabricating hair structures on man-made objects that not only have fine texture on the surface, but also can sense touch and be actuated.
SP. 386	surface	Cillia	In this paper we present Cillia, a bottom-up printing pipeline to fully utilize the capability of current high-resolution photopolymer 3D printers to generate large amounts of fine hair on the surfaces of 3D objects.

Código	Palavra-chave	Projeto	Palavra-chave em contexto
SP. 387	surface	Cilllia	We can quickly prototype objects with highly customized fine surface textures that have mechanical adhesion properties, or brushes with controllable stiffness and texture.
SP. 388	surface	Cilllia	An acoustic method for sensing finger swipe direction and velocity on hairy surfaces.
SP. 389	surface	Cilllia	Traditionally, synthetic hair/fur on a surface is produced with specific machining and chemical processes that have been widely used in fashion and product design.
SP. 390	surface	Cilllia	Recently, as materiality has become increasingly important in tangible interfaces design, researchers in HCI have presented works on rapid prototyping object with soft/furry surface textures.
SP. 391	surface	Cilllia	This enables designers to freely customize the surface detail of their design.
SP. 392	surface	Cilllia	In the context of design and HCI, we are interested in how to use hair to not only create fine surface texture, but also to utilize its structure to create active surfaces that can output physical motion and receive human gesture input.
SP. 393	surface	Cilllia	In the context of design and HCI, we are interested in how to use hair to not only create fine surface texture, but also to utilize its structure to create active surfaces that can output physical motion and receive human gesture input.
SP. 394	surface	Cilllia	Prior work shows a variety of approaches to actuate tabletop objects and touch sensing on surfaces.
SP. 395	surface	Cilllia	We demonstrate that by arranging the hair geometry and directionality on the surface with our tools, we can print surfaces that are capable of serving as both an actuating and sensing mechanism with help of a single transducer.
SP. 396	surface	Cilllia	We demonstrate that by arranging the hair geometry and directionality on the surface with our tools, we can print surfaces that are capable of serving as both an actuating and sensing mechanism with help of a single transducer.
SP. 397	surface	Cilllia	In this section, we introduce a novel approach to 3D print hair-like structure on both flat and curved surfaces.
SP. 398	surface	Cilllia	Although the resolution of recent 3d printers has been improving, it is still considered impractical to directly print fine hair arrays on object's surfaces.
SP. 399	surface	Cilllia	This is due to the lack of an efficient digital representation of CAD models with fine surface texture.
SP. 400	surface	Cilllia	In the field of computer graphics, the standard way to represent surface texture is through lofting bitmaps on the CAD model to create an optical illusion.
SP. 401	surface	Cilllia	Hair array on flat surfaces (2D): varying single hair geometry across the array on a 2D surface.
SP. 402	surface	Cilllia	Hair array on flat surfaces (2D): varying single hair geometry across the array on a 2D surface.
SP. 403	surface	Cilllia	Hair array on curved surfaces (3D): generating hair array on arbitrary curved surfaces.
SP. 404	surface	Cilllia	Hair array on curved surfaces (3D): generating hair array on arbitrary curved surfaces.
SP. 405	surface	Cilllia	Compared to other surfaces textures, such as wrinkle, hair is simpler to describe mathematically.
SP. 406	surface	Cilllia	It is usually a high aspect ratio cone that is vertical/angled to the surface.
SP. 407	surface	Cilllia	We successfully printed a series of sample surfaces with oriented hair.
SP. 408	surface	Cilllia	The ability to individually control hair geometry can be applied to thousands across a flat surface.
SP. 409	surface	Cilllia	In order to apply the presented techniques to a variety of models, it is desirable to print hair on an arbitrary curved surface.
SP. 410	surface	Cilllia	To do that, we developed a hybrid method; where user only create the curved surface in a CAD software, then generate bitmaps that contains pixels of hair array.
SP. 411	surface	Cilllia	There might be also parts of the hair that penetrate the nearby surface if the surface is curved inwards.

Código	Palavra-chave	Projeto	Palavra-chave em contexto
SP. 412	surface	Cillia	There might be also parts of the hair that penetrate the nearby surface if the surface is curved inwards.
SP. 413	surface	Cillia	In our test, we successfully printed 20000 strands of hair on a 30 by 60 mm flat surface. 3. Hair array can “grow” on any arbitrary CAD model while the model is being sliced.
SP. 414	surface	Cillia	This is because of the large amount of contact surface on the hair that creates friction.
SP. 415	surface	Cillia	As we can generate hair on curved surfaces, we can now 3D print animal figures with such features.
SP. 416	surface	Cillia	We push the hair surface against each other, and measured the force that was needed to pull them apart.
SP. 417	surface	Cillia	Similarly, the ciliary arrays lining the inside of our lungs produce surface standing waves that propel a mucus layer of contaminants over the surface.
SP. 418	surface	Cillia	Similarly, the ciliary arrays lining the inside of our lungs produce surface standing waves that propel a mucus layer of contaminants over the surface.
SP. 419	surface	Cillia	Inspired by those phenomena, we aim to 3D print a surface that can move passive object in contact with it.
SP. 420	surface	Cillia	Actuated surfaces in HCI have been widely studied.
SP. 421	surface	Cillia	Inspired by these previous works, Cillia encodes the motion on the surface into the structural design of the hair array.
SP. 422	surface	Cillia	A directional hair array on a surface creates anisotropic friction.
SP. 423	surface	Cillia	The vibration causes the legs to stick and slip on the horizontal surface, propelling the robot forward.
SP. 424	surface	Cillia	Cillia effectively inverts this bristle mechanism and leverages it to move objects on a surface without the need for precise control of an array of actuators
SP. 425	surface	Cillia	As we can fabricate hair with customized geometry and angles on both flat and curved surfaces, we demonstrate how to control the motion direction and velocity by manipulating the design of the hair.
SP. 426	surface	Cillia	Based on the surfaces where Cillia is arranged, we divide the moving paths into: 1. Hair on flat surface; and 2. Hair on curved surface.
SP. 427	surface	Cillia	Based on the surfaces where Cillia is arranged, we divide the moving paths into: 1. Hair on flat surface; and 2. Hair on curved surface.
SP. 428	surface	Cillia	We printed a series of 40 by 40 by 15 mm blocks. Each block contains a hair array with predefined orientation on the surface.
SP. 429	surface	Cillia	By controlling the orientation of the hair array on the flat surface, we can fabricate 2D surfaces that move passive objects in: 1. Straight line; 2. Curve line; and 3. Centered rotation.
SP. 430	surface	Cillia	By controlling the orientation of the hair array on the flat surface, we can fabricate 2D surfaces that move passive objects in: 1. Straight line; 2. Curve line; and 3. Centered rotation.
SP. 431	surface	Cillia	We also implemented a larger actuation surface by tiling small printed panel together.
SP. 432	surface	Cillia	The surface is designed to slide the objects on top to the middle and then move them to the right side.
SP. 433	surface	Cillia	We designed three applications to show how Cillia surface actuation mechanism can be use in the context of HCI.
SP. 434	surface	Cillia	Inspired by the works of Cymatics, we also use the surface of a speaker as a platform for actuating objects.
SP. 435	surface	Cillia	We firmly attached the two plates on their edges by gluing them on a 1” thick acrylic spacer, to ensure that only vertical vibration would conduct to the surface, as well as the vibration being propagated evenly through the surface.

Código	Palavra-chave	Projeto	Palavra-chave em contexto
SP. 436	surface	Cilllia	We firmly attached the two plates on their edges by gluing them on a 1” thick acrylic spacer, to ensure that only vertical vibration would conduct to the surface, as well as the vibration being propagated evenly through the surface.
SP. 437	surface	Cilllia	Sensing on the hair is interesting for us because the sensing mechanism and the surface texture can be seamlessly combined.
SP. 438	surface	Cilllia	We can now print a furry animal that senses petting without adding any electronics or obtrusive geometry on the surface of the figure.
SP. 439	surface	Cilllia	...we recorded 4 classes of swipes---forwards slow, forwards fast, backwards slow and backwards fast---along a flat cilllia surface with the piezo element attached to the bottom of the printed object with epoxy.
SP. 440	surface	Cilllia	In the third experiment, we recorded forwards and backwards swipes along a curved surface.
SP. 441	surface	Cilllia	The ability to sense finger swiping on the hair allows us to design interactive toys that combine the sensing mechanism and surface texture seamlessly.
SP. 442	surface	Cilllia	For example, if we had to create an arbitrarily shaped object that is fully covered by hair, we would have to split the object so that the curvature of the surface can still be printed without a supporting structure.
SP. 443	surface	Cilllia	Our current algorithm for generating hair on curved surfaces is also highly dependent on the amount and distribution of the triangles of the CAD model.
SP. 444	surface	Cilllia	We present a method of 3D printing hair-like structures on both flat and curved surfaces.
SP. 445	surface	Materiable	However, works in haptic devices either remain in a flat static surfaces or require additional wearable/hand-held devices that target sensations to specific parts of the body.
SP. 446	surface	Materiable	For example, jamming techniques have often been used to dynamically change stiffness of the interface and connect this change to content represented on the jammable material surface with projection.
SP. 447	surface	Materiable	This shape display also has a projector mounted to provide graphic feedback on top of the surface of pins.
SP. 448	surface	Materiable	With the ad-hoc constraint in place, the model simulates a believable foam or mattress surface, depending on how the parameters are tuned.
SP. 449	surface	Materiable	Previous work refers to how one can extend the 2D heightfield model to have an adaptive 3D surface with splashing.
SP. 450	surface	Materiable	For example, CAD applications are split into solid modelers, which involve boolean and parametric operations on “solid” parts while surface modelers usually render the model only has a surface to be manipulated and deformed as a mesh.
SP. 451	surface	Materiable	For example, CAD applications are split into solid modelers, which involve boolean and parametric operations on “solid” parts while surface modelers usually render the model only has a surface to be manipulated and deformed as a mesh.
SP. 452	surface	Materiable	A more liquid or viscous rendered material property might afford a surface model approach where deformations are direct and local.
SP. 453	surface	Materiable	Although the surface texture on our implementation was polystyrene, improving the resolution of shape display could provide fine tactile feedback.



## Forma (*Shape*)

Código	Palavra-chave	Projeto	Palavra-chave em contexto
FO. 1	shape	CurlyBot	This activity introduces a child to the idea of building complex shapes by combining simpler elements.
FO. 2	shape	CurlyBot	About a quarter of the children (21 out of 81), explicitly created geometric shapes.
FO. 3	shape	CurlyBot	One ten-year-old girl, for example, recorded a beautiful geometric piece after observing four boys of her age record strictly geometric shapes.
FO. 4	shape	CurlyBot	However, unlike the boys, her geometric shapes had accelerations and pauses, which created a more gestural pattern.
FO. 5	shape	CurlyBot	Two, this version of curlybot was not designed to reproduce fast motions as accurately as slow ones and, as a result, curlybot did not repeat geometric shapes perfectly.
FO. 6	shape	CurlyBot	We found that she needed us to provide an example before being able to create the shapes on her own.
FO. 7	shape	CurlyBot	Later on, the same girl came back, and asked if she could try a shape she had been thinking about.
FO. 8	shape	CurlyBot	We were pleased to see that she continued to process her new knowledge about shapes even outside the play area. curlybot appears to have become an object-to-think-with for her.
FO. 9	shape	Urp	Urp now provides a distance-tool (shaped like a pencil but with the image of a ruler stretching between the pencil tip and eraser) that can be used to connect together selected structures.
FO. 10	shape	Urp	Placing this arrow-shaped tool within the field samples and numerically displays the flow magnitude at the precise position of the tool's tip.
FO. 11	shape	Urp	The shapes of these objects are extracted from the visual field captured by the I/O Bulb using rudimentary frame-differencing techniques; these silhouette shapes then serve as obstacles appropriately positioned within the flow simulation's boundary.
FO. 12	shape	Urp	The shapes of these objects are extracted from the visual field captured by the I/O Bulb using rudimentary frame-differencing techniques; these silhouette shapes then serve as obstacles appropriately positioned within the flow simulation's boundary.
FO. 13	shape	Urp	The arbitrary objects that act as flow obstacles in the seep application are one example: there, nothing matters but the shape of what's placed in the workspace; all other attributes of the objects used are ignored.
FO. 14	shape	Sensetable	The pucks have two sockets inside of a crescent shaped recess on their top surfaces, shown in figure 3.
FO. 15	shape	Sensetable	This led one user to comment that pen or wand shaped objects might make more sense for manipulating the data, because they would not obscure so much of the information in front of them on the table.
FO. 16	shape	Sensetable	The new surface is constructed from 25 cm square sensing boards, which can be tiled to form sensing areas of varying size and shape.
FO. 17	shape	Illuminating Clay	Distortions in the shape of this stripe are captured by a camera mounted in the scanner, which is offset by a known distance from the source of the laser stripe.
FO. 18	shape	Illuminating Clay	This in turn requires the necessity to use purpose-built objects that are of a suitable size, shape or material to accept the tracking mechanism preventing the user from freely choosing objects that suite their particular needs.
FO. 19	shape	Sandscape	The tabletop is shaped as a square torus ('square bagel') and holds 30 pounds of glass beads in the centre cavity.
FO. 20	shape	PICO	The experimenter explained that a disc could be placed on top of an object to stop it from moving, and the barrier could be bent into any shape to constrain the motion of the pucks.

Código	Palavra-chave	Projeto	Palavra-chave em contexto
FO. 21	shape	PICO	Topobo includes Passives (static parts) and Actives (networkable, motorized parts) that can be snapped together to form models of animals, regular geometries, or abstract shapes.
FO. 22	shape	PICO	The “elbow” (offset 90o) comes in one size. The “straight,” “T,” “L” (90o), and “tetra” (108o) shapes come in two sizes with a scale ratio 2:3, based on the Fibonacci ratio that describes scaling in growing systems like mammalian skeletons.
FO. 23	shape	PICO	For example, two straight pieces will form a “+” shape, or two tetras will form a tetrahedron.
FO. 24	shape	PICO	The Actives are motorized, networkable, egg-shaped plastic objects with a button and an LED for indicating whether the system is in record (red) or playback (green) mode.
FO. 25	shape	Relief	Relief is an actuated tabletop display, which is able to render and animate three-dimensional shapes with a malleable surface.
FO. 26	shape	Relief	An example of this domain is shape displays, which can change their physical appearance to provide a haptic 3 dimensional experience in addition to graphic output.
FO. 27	shape	Relief	While a number of approaches to create shape display have been proposed, most of them are complex to build and therefore often unavailable to the HCI community.
FO. 28	shape	Relief	The display is both able to render shapes and sense user input through a malleable surface, which is actuated by an array of electric slide potentiometers.
FO. 29	shape	Relief	A well-known example of a shape display is FEELEX by Iwata et al., where 36 motorized pins actuate the shape of a soft surface, onto which graphics are projected.
FO. 30	shape	Relief	A well-known example of a shape display is FEELEX by Iwata et al., where 36 motorized pins actuate the shape of a soft surface, onto which graphics are projected.
FO. 31	shape	Relief	Lumen by Poupyrev et al. utilizes shape memory alloy to actuate pixels on a tabletop display.
FO. 32	shape	Relief	Electric slide potentiometers have previously been utilized to create actuated arrays for sensing user input and rendering shapes, such as in AR-Jig by Anabuki and Ishii-
FO. 33	shape	Relief	The same program also outputs graphics, which are projected back onto the tabletop to augment the shape display.
FO. 34	shape	Relief	Relief is the first version of an actuated shape display based on our scalable hardware platform.
FO. 35	shape	Relief	Human beings have long shaped the physical environment to reflect designs of form and function
FO. 36	shape	Relief	In the wake of the digital revolution, where we have extended our existence beyond tangible form, we ask this question—what if we could dynamically reshape, redesign, and restructure our environment using the functional nature of digital tools?
FO. 37	shape	Relief	The shape of the interface provides passive feedback on the modeling operations, but does not represent the geometry of the CAD model.
FO. 38	shape	Relief	Both Project Feelex by Iwata et al. and Lumen by Poupyrev et al. present shape displays with input sensing capabilities.
FO. 39	shape	Relief	These advanced functions are proven cornerstones in three-dimensional modeling and shape design.
FO. 40	shape	ZeroN	Poupyrev, et.al provide an excellent overview of shape displays.
FO. 41	shape	ZeroN	Despite their compelling qualities as shape display, they share two common limitations as interfaces.
FO. 42	shape	JammingUI	Malleable and organic user interfaces have the potential to enable radically new forms of interactions and expressiveness through flexible, free-form and computationally controlled shapes and displays.

Código	Palavra-chave	Projeto	Palavra-chave em contexto
FO. 43	shape	JammingUI	This work, specifically focuses on particle jamming as a simple, effective method for flexible, shape-changing user interfaces where programmatic control of material stiffness enables haptic feedback, deformation, tunable affordances and control gain.
FO. 44	shape	JammingUI	We introduce a compact, low-power pneumatic jamming system suitable for mobile devices, and a new hydraulic-based technique with fast, silent actuation and optical shape sensing.
FO. 45	shape	JammingUI	We enable jamming structures to sense input and function as interaction devices through two contributed methods for high-resolution shape sensing using: 1) index-matched particles and fluids, and 2) capacitive and electric field sensing.
FO. 46	shape	JammingUI	We explore the design space of malleable and organic user interfaces enabled by jamming through four motivational prototypes that high-light jamming's potential in HCI, including applications for tabletops, tablets and for portable shape-changing mobile devices.
FO. 47	shape	JammingUI	Organic User Interfaces (OUIs) embrace the advances of new technology and materials to enable deformable and actuated interfaces of arbitrary shapes.
FO. 48	shape	JammingUI	This enables drastic and reversible shape deformations using a single embedded actuator.
FO. 49	shape	JammingUI	Extremely flexible materials such as silicone can be utilized in jamming devices, allowing the system to be stretched, twisted, or bent with the jamming material flowing easily into these new shapes.
FO. 50	shape	JammingUI	This makes jamming an ideal candidate for enabling malleable and shape changing user interfaces.
FO. 51	shape	JammingUI	A successful application of jamming to HCI requires advances in sensing to detect shape deformations and user input, as well as actuation for providing feedback to the user.
FO. 52	shape	JammingUI	This, in combination with our embedded shape sensing, demonstrate the potential for novel interactions and increased expressiveness.
FO. 53	shape	JammingUI	Shape-changing user interfaces can provide users with more affordances for different tasks, allow for greater tactile manipulability, or provide haptic feedback by changing their physical form.
FO. 54	shape	JammingUI	Inflatable interfaces have been introduced that allow displays or objects to quickly change shape, or to inform the user of program state.
FO. 55	shape	JammingUI	Jam- ming can enable this type of interaction, by increasing the rigidity of a certain shape, while remaining easily actuated in another.
FO. 56	shape	JammingUI	In addition, unlike many shape-changing interfaces, jamming interfaces may be user defined and provide a wide design space of possible shapes
FO. 57	shape	JammingUI	In addition, unlike many shape-changing interfaces, jamming interfaces may be user defined and provide a wide design space of possible shapes.
FO. 58	shape	JammingUI	It consists of a soft mesh that can morph into different shapes through computer controlled pneumatic cells.
FO. 59	shape	JammingUI	Jammable chambers in the skin of the interface solidify the shape when its deformation goal is reached.
FO. 60	shape	JammingUI	HoverMesh focuses on actuated shape output and does not implement user input through deformation sensing, although the authors discuss the possibility of employing computer vision methods or embedded bend sensors as a future work.
FO. 61	shape	JammingUI	This section provides an overview of how jamming activation techniques enable the control of shape and material stiffness, and thus the degree to which a volume can be physically modified or actuated.

Código	Palavra-chave	Projeto	Palavra-chave em contexto
FO. 62	shape	JammingUI	The application of jamming has great potential to complement shortcomings of traditional shape-changing devices.
FO. 63	shape	JammingUI	In addition, due to its unique abilities to affect shape dynamics and kinetics, jamming is valuable as a standalone modality.
FO. 64	shape	JammingUI	Malleable interfaces typically need to both enable effortless deformation, while also providing mechanisms to stabilize resulting freeform shapes.
FO. 65	shape	JammingUI	In addition to deformation in the unjammed state, and solidification of the resulting shape in the maximally jammed state, there are interesting nuances related to expression and fidelity in the range of stiffness levels in-between.
FO. 66	shape	JammingUI	The type of deformation that is possible, and its effect on the overall shape, depends on material stiffness.
FO. 67	shape	JammingUI	It is thus possible to tune the control gain to tweak the precision and scale of user manipulations of the material shape.
FO. 68	shape	JammingUI	Most actuation techniques for shape displays employ active elements to displace different types of media.
FO. 69	shape	JammingUI	While jamming does not provide actuation per se, it enables straight-forward “locking” and “unlocking” of continuous freeform shapes with varying stiffness using a single actuator.
FO. 70	shape	JammingUI	To change a jamming structure’s shape dramatically, another source of actuation is necessary: either a passive source, such as the user’s force or gravity, or an active source, such as a pneumatic air muscle.
FO. 71	shape	JammingUI	In addition to augmenting existing actuation techniques, novel actuators based on jamming structures could enable completely different shape-changing interfaces.
FO. 72	shape	JammingUI	Passive, deformable shapes, with elastic or spring-loaded properties can also be added to the volume to provide restoring forces, so that when unjammed, the device returns to a certain shape.
FO. 73	shape	JammingUI	Passive, deformable shapes, with elastic or spring-loaded properties can also be added to the volume to provide restoring forces, so that when unjammed, the device returns to a certain shape.
FO. 74	shape	JammingUI	The single actuator used to jam the particles may not only be used to accelerate the unjamming in reverse-operation, but could also be employed for inflation the jamming shape (similar to the technique described by Amend et al.).
FO. 75	shape	JammingUI	By drastically changing the particle/medium ratio through inflation, we can allow the fluid jamming medium to dominate the shape volume and the user’s experience of it.
FO. 76	shape	JammingUI	It is often desirable to sense users’ freeform deformations of malleable devices, including 3D shapes, as well as interaction on and above surfaces.
FO. 77	shape	JammingUI	Shape deformation can, besides the direct 1:1 manipulation of geometry representations, also be used in pattern-matching of shapes.
FO. 78	shape	JammingUI	The effect that different particle properties, such as size and shape, have on jamming performance has been extensively studied.
FO. 79	shape	JammingUI	For shape-changing interfaces, we are interested in particles that could achieve large changes in stiffness and jam in arbitrary freeform shapes.
FO. 80	shape	JammingUI	Jamming has great potential in enabling haptic feedback, malleable input, and shape-changing structures for flexible mobile devices, such as future tablets, e-readers or cell phones.

Código	Palavra-chave	Projeto	Palavra-chave em contexto
FO. 81	shape	JammingUI	In this section, we discuss approaches that are particularly suitable to enable the shape and touch sensing that is necessary to leverage the flexibility and malleability of jamming structures for HCI.
FO. 82	shape	JammingUI	To enable optical sensing of the interface's 3D shape, while avoiding user interference, occlusion and bulky system configurations, it is necessary to integrate cameras below the surface.
FO. 83	shape	JammingUI	This device enables the use of different optical techniques for surface reconstruction, such as shape from shading, photometric stereo, embedded tracking markers in the skin, structured lighting, or other custom solutions.
FO. 84	shape	JammingUI	While this approach provides high-resolution shape and deformation tracking combined with touch sensing, its use is limited to hydraulic jamming systems.
FO. 85	shape	JammingUI	Capacitive sensing can provide a scalable embedded approach to sensing shape in jamming interfaces, including deformations such as stretching, bending and twisting.
FO. 86	shape	JammingUI	In contrast to other techniques, such as resistive pressure sensors or electric impedance tomography, capacitive distance and shape sensing do not rely on a present applied force to the sensor.
FO. 87	shape	JammingUI	Using rows of transmitting electrodes in a rigid back, and columns of receiving electrodes in a flexible skin, we sense the jammable volume's shape through time-division-multiplexing for each of the intersections in the sensing matrix and output a 2.5D depth map.
FO. 88	shape	JammingUI	Our prototype of the capacitive shape-sensing input device with jamming haptic feedback uses a 9→9 electrode grid.
FO. 89	shape	JammingUI	Separating transmitting and receiving electrodes into rows and columns for deformation sensing is only one approach to capacitive shape sensing electrode layouts; additionally, each electrode can act as both a transmitter and receiver.
FO. 90	shape	JammingUI	Time-division-multiplexing makes it possible to use the receiving electrodes both for shape-sensing electrodes below, and touch-sensing electrodes above, which reduces the total number of required electrodes for shape and touch sensing.
FO. 91	shape	JammingUI	Time-division-multiplexing makes it possible to use the receiving electrodes both for shape-sensing electrodes below, and touch-sensing electrodes above, which reduces the total number of required electrodes for shape and touch sensing.
FO. 92	shape	JammingUI	Optical sensing—achieved using structured light through the back of the transparent, hydraulic activated jamming volume—captures the shape in real-time and applies it to a virtual 3D model.
FO. 93	shape	JammingUI	One can increase the stiffness of the interface for detailed work, decrease it to increase malleability or to reset the shape.
FO. 94	shape	JammingUI	The transparency and shape of the lens also make it possible to provide users with optically magnified view of the objects they are touching.
FO. 95	shape	JammingUI	A custom tablet case has an embedded jamming apparatus and shape deformation sensor for malleable inter- action in the back of the tablet.
FO. 96	shape	JammingUI	The mobile jamming platform is pneumatically controlled with an on-board vacuum pump and uses capacitive shape sensing.
FO. 97	shape	JammingUI	he first uses Bluetooth to communicate the capacitive shape sensing and jamming control to a tablet, which runs our Android application.
FO. 98	shape	JammingUI	ShapePhone, depicted in Figure 14, is a user-defined mobile device that can be shaped into different forms and then locked into a rigid device for various forms of interaction.
FO. 99	shape	JammingUI	ShapePhone, depicted in Figure 14, is a user-defined mobile device that can be shaped into different forms and then locked into a rigid device for various forms of interaction.

Código	Palavra-chave	Projeto	Palavra-chave em contexto
FO. 100	shape	JammingUI	With our initial ShapePhone prototype users can transform the affordance of the device—from a phone, tablet (sheet), remote control, watch, game controller, or ball—by stretching, bending and molding ShapePhone when it is unjammed and thus extremely pliable, due to the stretchy silicone skin.
FO. 101	shape	JammingUI	With our initial ShapePhone prototype users can transform the affordance of the device—from a phone, tablet (sheet), remote control, watch, game controller, or ball—by stretching, bending and molding ShapePhone when it is unjammed and thus extremely pliable, due to the stretchy silicone skin.
FO. 102	shape	JammingUI	When unjammed, ShapePhone returns to its normal state of a phone-sized rectangle, using the silicone skin as a restoring force.
FO. 103	shape	JammingUI	Our prototype uses the Mobile Jamming Platform, described earlier, to control jamming in a small form factor, and enables ShapePhone to be entirely self-contained.
FO. 104	shape	JammingUI	The phone-shaped hollow silicone (Smooth-On EcoFlex 0030) body was cast from a 3D-printed three-part mold.
FO. 105	shape	JammingUI	It would be relatively straightforward to add the previously described capacitive shape sensing techniques to ShapePhone to sense a variety of different shapes.
FO. 106	shape	JammingUI	It would be relatively straightforward to add the previously described capacitive shape sensing techniques to ShapePhone to sense a variety of different shapes.
FO. 107	shape	JammingUI	It would be relatively straightforward to add the previously described capacitive shape sensing techniques to ShapePhone to sense a variety of different shapes.
FO. 108	shape	JammingUI	These shapes could be used in addition to contextual information gathered through other sensors, or program state, to enable further functionality.
FO. 109	shape	JammingUI	Changes in stiffness could convey battery life, for example, letting the ShapePhone “melt” when it runs out of battery, or allowing user input through the pocket using squeezes or deformations.
FO. 110	shape	JammingUI	When designing a jamming system with shape and touch sensing, several design decisions are of importance, as demonstrated in our approaches for activation, sensing, and interactive applications and prototypes.
FO. 111	shape	JammingUI	Hydraulic jamming enables optical shape and touch sensing through transparent volumes, and provides strong, rapid and silent operation.
FO. 112	shape	JammingUI	Techniques, such as pneumatic artificial muscles, as well as other inflatable structures, could be used to quickly change state and help jamming enable an even wider array of shape-changing interfaces.
FO. 113	shape	JammingUI	We plan to investigate other approaches to embedded electrodes and wiring, such as embedded liquid metal and saltwater, for stretchable capacitive shape sensing.
FO. 114	shape	JammingUI	This work demonstrates how jamming of granular particles can be applied to malleable, flexible and shape-changing user interfaces, and the interaction vocabulary made possible through programmable stiffness and control of material properties.
FO. 115	shape	JammingUI	By embedding sensing through index-matched optical sensing or capacitive shape sensing, we enable jamming interfaces to become high-resolution input devices.
FO. 116	shape	inFORM	Past research on shape displays has primarily focused on rendering content and user interface elements through shape output, with less emphasis on dynamically changing UIs.
FO. 117	shape	inFORM	We propose utilizing shape displays in three different ways to mediate interaction: to facilitate by providing dynamic physical affordances through shape change, to restrict by guiding users with dynamic physical constraints, and to manipulate by actuating physical objects.

Código	Palavra-chave	Projeto	Palavra-chave em contexto
FO. 118	shape	inFORM	We propose utilizing shape displays in three different ways to mediate interaction: to facilitate by providing dynamic physical affordances through shape change, to restrict by guiding users with dynamic physical constraints, and to manipulate by actuating physical objects.
FO. 119	shape	inFORM	We outline potential interaction techniques and introduce Dynamic Physical Affordances and Constraints with our inFORM system, built on top of a state-of-the-art shape display, which provides for variable stiffness rendering and real-time user input through direct touch and tangible interaction.
FO. 120	shape	inFORM	To overcome these limitations, we seek to bring the dynamism of visually perceived affordances of GUIs to physical interaction by utilizing shape-changing UIs.
FO. 121	shape	inFORM	This paper explores Dynamic Affordances which can transform shape, size, location and orientation, in addition to being able to appear and disappear.
FO. 122	shape	inFORM	In addition to creating affordances and constraints for physical objects and tools, we also show how shape change can be utilized to manipulate passive objects.
FO. 123	shape	inFORM	To explore these techniques and interactions, we introduce the inFORM system, a state-of-the-art 2.5D shape display that enables dynamic affordances, constraints and actuation of passive objects.
FO. 124	shape	inFORM	Shape displays allow for more general-purpose shape change than many other actuated or shape-changing interfaces, and thus are ideal research platforms.
FO. 125	shape	inFORM	Shape displays allow for more general-purpose shape change than many other actuated or shape-changing interfaces, and thus are ideal research platforms.
FO. 126	shape	inFORM	Shape displays allow for more general- purpose shape change than many other actuated or shape-changing interfaces, and thus are ideal research platforms.
FO. 127	shape	inFORM	While shape displays still remain limited in scale and cost, this work is an exploration of the interaction capabilities and is meant to inspire further research in this area.
FO. 128	shape	inFORM	Our belief is that shape-changing interfaces will become increasingly available in the future, and this work tries to push towards creating a vocabulary and design space for more general-purpose interaction for shape displays, including rendering of both content and UI elements.
FO. 129	shape	inFORM	Our belief is that shape-changing interfaces will become increasingly available in the future, and this work tries to push towards creating a vocabulary and design space for more general-purpose interaction for shape displays, including rendering of both content and UI elements.
FO. 130	shape	inFORM	In this paper, we first review related work in physical affordances and constraints, as well as shape-changing interfaces and dynamic affordances.
FO. 131	shape	inFORM	Actuation of physical objects through shape displays.
FO. 132	shape	inFORM	State-of-the-art system for fast, real-time 2.5D shape actuation, co-located projected graphics, object tracking, and direct manipulation.
FO. 133	shape	inFORM	In this paper, we focus on rendering both cognitive affordances and physical affordances through a shape display.
FO. 134	shape	inFORM	Physical form can be used as a cognitive affordance, i.e., rendering a physical play button shaped like a triangle, which could be primarily perceived visually but also tactilely.
FO. 135	shape	inFORM	Coelho and Zigelbaum and Rasmussen et al. review the design spaces for shape-changing interfaces, where actuation actively modifies the shape of an interface or object.
FO. 136	shape	inFORM	Coelho and Zigelbaum and Rasmussen et al. review the design spaces for shape-changing interfaces, where actuation actively modifies the shape of an interface or object.

Código	Palavra-chave	Projeto	Palavra-chave em contexto
FO. 137	shape	inFORM	Most current shape-changing interfaces that address on-demand affordances provide a specific transformation, which limits their use for general purpose UIs and 3D interaction.
FO. 138	shape	inFORM	The haptic chameleon by Michelitsch et al. introduces the concept of shape-changing control devices and reports on experiments with early prototypes.
FO. 139	shape	inFORM	Shape displays, which enable more general topologies and greater degrees-of-freedom, tend to primarily focus on content representation through graphics and shape; the generated shapes can respond to the user's touch, gestures, or other objects' presence.
FO. 140	shape	inFORM	Shape displays, which enable more general topologies and greater degrees-of-freedom, tend to primarily focus on content representation through graphics and shape; the generated shapes can respond to the user's touch, gestures, or other objects' presence.
FO. 141	shape	inFORM	Shape displays, which enable more general topologies and greater degrees-of-freedom, tend to primarily focus on content representation through graphics and shape; the generated shapes can respond to the user's touch, gestures, or other objects' presence.
FO. 142	shape	inFORM	The use of a general-purpose 2.5D shape display allows us to support dynamic adaptation of the form, based on user interaction, application context and scenario.
FO. 143	shape	inFORM	Past research on shape displays has primarily focused on rendering content through shape output, with less emphasis on investigating dynamically changing UI elements.
FO. 144	shape	inFORM	We believe that shape displays need to provide three types of functionality for creating dynamic UIs: to facilitate through Dynamic Affordances, to restrict through Dynamic Constraints, and to manipulate passive objects through shape change.
FO. 145	shape	inFORM	We believe that shape displays need to provide three types of functionality for creating dynamic UIs: to facilitate through Dynamic Affordances, to restrict through Dynamic Constraints, and to manipulate passive objects through shape change.
FO. 146	shape	inFORM	Affordances can change shape to reflect a changing program state.
FO. 147	shape	inFORM	For example, when a user presses a play button (triangle shape) it can transform into a stop button (square shape).
FO. 148	shape	inFORM	For example, when a user presses a play button (triangle shape) it can transform into a stop button (square shape).
FO. 149	shape	inFORM	Shape-changing affordances can also enable smooth transitions between input dimensions. For example, pressing a button could cause it to transform into a 2D touch panel.
FO. 150	shape	inFORM	It can be advantageous to let the user's proximity inform shape change.
FO. 151	shape	inFORM	When an object is placed on a shape display, it physically interacts with the shapes generated by the display.
FO. 152	shape	inFORM	In the context of our work, we refer to the physical objects as tokens and the shapes interacting with them as constraints.
FO. 153	shape	inFORM	Constraints like wells, slots and ramps limit the movement of the token through their shape, thus guiding user interaction, similar to...
FO. 154	shape	inFORM	As our system can sense how tokens interact with constraints, it can dynamically modify their parameters (shape, size, location, orientation) to adapt to user input or to reflect changing program states.
FO. 155	shape	inFORM	Examples of techniques to guide interactions using shape change.
FO. 156	shape	inFORM	The shape of the well and the shape of the token determine if the token can be rotated in the well, which adds another degree of freedom.
FO. 157	shape	inFORM	Wells can transform in size and shape to adapt to the size, shape and number of tokens.



Código	Palavra-chave	Projeto	Palavra-chave em contexto
FO. 158	shape	inFORM	Wells can transform in size and shape to adapt to the size, shape and number of tokens.
FO. 159	shape	inFORM	Slots change in size, shape and location to reflect a changing program state.
FO. 160	shape	inFORM	As the user moves the item inside the well, its shape can transform and branch out to present selectable options.
FO. 161	shape	inFORM	Slots can also transform their shape to promote the movement of tokens in a certain direction or to hinder it.
FO. 162	shape	inFORM	An ex- ample is shown in Figure 5 (right), where a ramp-shaped slot allows users to roll a token with ease in the direction sloping downwards, while requiring deliberate effort to move it in the upwards direction.
FO. 163	shape	inFORM	Shape displays can appropriate passive objects by independently actuating and manipulating them to create dynamic affordances and constraints.
FO. 164	shape	inFORM	The shape display can apply mechanical force to an object and cause it to move in a variety of ways.
FO. 165	shape	inFORM	Additionally, it allows the shape display to output greater degrees of freedom (e.g., lateral movement), and enables greater degrees of freedom afforded to the user for input.
FO. 166	shape	inFORM	Our techniques for actuating passive objects do not require an active or special material (such as magnets), but instead manipulate geometrical shapes, with the limitation that certain geometries (such as a ball) are easier to move than others.
FO. 167	shape	inFORM	Other factors to consider include the mass of the object, the force of the motors, and the friction between the shape display surface and the passive object.
FO. 168	shape	inFORM	Secondly, given the right shape, the vertical actuator movement can push an object sideways or induce rolling.
FO. 169	shape	inFORM	Currently only certain objects, with conical or rectangular shapes can be rotated.
FO. 170	shape	inFORM	These objects can be of arbitrary shape or make use of the space in-between the actuators.
FO. 171	shape	inFORM	The constraints defined by the shape display surface could also be user defined, for instance, by deforming the shapes directly with bare hands.
FO. 172	shape	inFORM	... Gibson lists a number of such properties: "When the constant properties of constant objects are perceived (the shape, size, color, texture, composition, motion, animation, and position relative to other objects), the observer can go on to detect their affordances."
FO. 173	shape	inFORM	Shape-changing interfaces, on the other hand, have the ability to add such parameters, and can be categorized as changes in orientation, form, volume, texture, viscosity, spatiality, adding/subtracting, and permeability.
FO. 174	shape	inFORM	We find it attractive to utilize 2.5D shapes display to render physical affordances, as their hardware capabilities enable simultaneous control over multiple parameters.
FO. 175	shape	inFORM	The shape of UI elements can provide multiple affordances, real affordances (how the shape can be touched), and cultural affordances (what the shape represents).
FO. 176	shape	inFORM	The shape of UI elements can provide multiple affordances, real affordances (how the shape can be touched), and cultural affordances (what the shape represents).
FO. 177	shape	inFORM	The shape of UI elements can provide multiple affordances, real affordances (how the shape can be touched), and cultural affordances (what the shape represents).
FO. 178	shape	inFORM	This creates interesting interface design challenges that must be considered, in particular, for 2.5D shape display hardware.
FO. 179	shape	inFORM	While these can be dynamically modified, users cannot easily grasp, lift and rearrange objects on 2.5D shape displays.

Código	Palavra-chave	Projeto	Palavra-chave em contexto
FO. 180	shape	inFORM	Therefore, we propose to complement them with passive physical tokens that enable these interactions, while they can also be constrained and actuated by the display surface shape.
FO. 181	shape	inFORM	The bristles of the brush move smoothly over the shape display surface, while being optically tracked by the system.
FO. 182	shape	inFORM	Pin height and stiffness is represented in software as an 8-bit height map, which can be produced by OpenGL shaders, through different shape primitive classes, or by directly writing data.
FO. 183	shape	inFORM	Therefore, the power consumption to maintain a shape is less than 300 W...
FO. 184	shape	inFORM	While stiffness can be controlled, pin shape, spacing and material choices limit the affordances and constraints that the system can generate and how they interact with external objects.
FO. 185	shape	inFORM	We, however, believe that the system's spacing, resolution and the interactive speeds rendered, are sufficient to allow the prototyping of many interactions that would be challenging on other existing shape displays.
FO. 186	shape	inFORM	The current cost and scale of our shape display hardware limits its primarily use to research.
FO. 187	shape	inFORM	Shape displays allow for new ways to create physical interfaces, beyond functionality alone.
FO. 188	shape	inFORM	Shape displays begin to let interface designers create radically different physical forms for different applications.
FO. 189	shape	inFORM	It also points towards uses of shape displays for prototyping new physical interfaces.
FO. 190	shape	inFORM	While we believe the main reasons to be the limited resolution of the shape display hardware and the software not adapting well to content changes, solving the physical overlap of content and interface elements rendered both as shapes is a very interesting new challenge of such interfaces.
FO. 191	shape	inFORM	While we believe the main reasons to be the limited resolution of the shape display hardware and the software not adapting well to content changes, solving the physical overlap of content and interface elements rendered both as shapes is a very interesting new challenge of such interfaces.
FO. 192	shape	inFORM	We also noticed on multiple occasions how rapid shape transitions were jarring to users, an observation we have made in earlier studies as well-
FO. 193	shape	inFORM	The question remains how to best communicate shape transitions to the user before they occur, to avoid surprise.
FO. 194	shape	inFORM	We see this question as an important next step for research on shape displays.
FO. 195	shape	inFORM	Smooth transitions may not suffice to adequately inform the user; possibilities for shape change may need to be more legible.
FO. 196	shape	inFORM	Or, one potential direction to explore legibility for potential shape change could be to combine shape change with augmented reality, similar to...
FO. 197	shape	inFORM	Or, one potential direction to explore legibility for potential shape change could be to combine shape change with augmented reality, similar to...
FO. 198	shape	inFORM	More theoretically, considering the shape display as an autonomous agent, may suggest looking towards research in human—robot interaction, where robots may want to convey to the user how they will move through more subtle means.
FO. 199	shape	inFORM	We described two ways to move a ball on the shape display surface: pushing the ball or rolling it down a slope.
FO. 200	shape	inFORM	We believe that the facilitate, restrict and manipulate techniques described here are merely one part of a larger space of Dynamic Physical Affordances, which will emerge as shape-changing UIs mature.

Código	Palavra-chave	Projeto	Palavra-chave em contexto
FO. 201	shape	inFORM	However, it is interesting to look at the larger space of possibilities for actuation and shape change: the user, the tool handle, tool, object, and physical surface must be considered.
FO. 202	shape	inFORM	For example, a tool can change shape as the interaction surfaces change shape as well.
FO. 203	shape	inFORM	For example, a tool can change shape as the interaction surfaces change shape as well.
FO. 204	shape	inFORM	It is at these intersections between different materials and different interaction elements where shape change and actuation begin to open new opportunities for human—computer interaction.
FO. 205	shape	inFORM	We believe that proxemic interaction for shape-changing UIs is another important area to explore, as well as multi-user collaboration, co-located and remote.
FO. 206	shape	inFORM	In this work we have explored the design space of Dynamic Physical Affordances and Constraints, and described methods for actuating physical objects on actuated shape displays.
FO. 207	shape	inFORM	Many prior approaches to shape-changing user interfaces have relied on special-purpose or bistable shape change.
FO. 208	shape	inFORM	Many prior approaches to shape-changing user interfaces have relied on special-purpose or bistable shape change.
FO. 209	shape	inFORM	Instead, we explored dynamic shape change's more general-purpose role, similar to the flexibility of a bitmap screen for GUIs.
FO. 210	shape	inFORM	This opens possibilities for using shape change both for content and as a UI elements.
FO. 211	shape	inFORM	Dynamic Physical Affordances and Constraints encompass a large space of features that we hope will inspire designers when creating shape-changing interfaces.
FO. 212	shape	Sublimate	Recent research in 3D user interfaces pushes towards immersive graphics and actuated shape displays.
FO. 213	shape	Sublimate	We discuss how digital models, handles and controls can be interacted with as virtual 3D graphics or dynamic physical shapes, and how user interfaces can rapidly and fluidly switch between those representations.
FO. 214	shape	Sublimate	To explore this space, we developed two systems that integrate actuated shape displays and augmented reality (AR) for co-located physical shapes and 3D graphics.
FO. 215	shape	Sublimate	To explore this space, we developed two systems that integrate actuated shape displays and augmented reality (AR) for co-located physical shapes and 3D graphics.
FO. 216	shape	Sublimate	We conclude by discussing the results from a user study that show how freehand interaction with physical shape displays and co-located graphics can outperform wand-based interaction with virtual 3D graphics.
FO. 217	shape	Sublimate	Another approach is to render the actual shape of physical objects, as proposed by research visions like “Claytronics” and “Radical Atoms”.
FO. 218	shape	Sublimate	Systems following this approach include shape displays, which utilize actuators to render objects that users can see, touch and manipulate with bare hands.
FO. 219	shape	Sublimate	Current generation shape displays trade the advantages of real objects for the flexibility and realism of high-resolution graphics in VR interfaces.
FO. 220	shape	Sublimate	Thus we are not only interested in augmenting shape displays with graphics, or adding haptic feedback to AR, but also how the transition between physical and virtual can enable new user interactions.
FO. 221	shape	Sublimate	In order to explore this space of virtual/physical state transitions, we designed two implementations of a system called Sublimate, which combines spatial AR with actuated shape displays.

Código	Palavra-chave	Projeto	Palavra-chave em contexto
FO. 222	shape	Sublimate	The first combines a optical see-through AR display, utilizing a stereo display, acrylic beam-splitter, and head tracking, with a shape display to co-locate 3D virtual graphics and a physical 2.5D surface.
FO. 223	shape	Sublimate	Both systems allow for direct interaction from the user, through mid-air interaction with a wand and through physical manipulation of the shape display.
FO. 224	shape	Sublimate	We describe prototype applications to demonstrate the concept and document the implementation details of our two systems for augmenting shape displays.
FO. 225	shape	Sublimate	We then report on a formal evaluation of our system that investigates different input styles with 3D content on a spatial optical see-through display combined with shape output.
FO. 226	shape	Sublimate	We discuss these results, which indicate that interacting through direct touch on a shape display can be faster than mid-air manipulation with a wand, and present user feedback on the Sublimate system.
FO. 227	shape	Sublimate	Practical implementations to prototype interactions combining actuated shape display with co-located 3D graphics, using optical see-through spatial AR displays and handheld video see-through AR devices.
FO. 228	shape	Sublimate	Extension of a shape display's resolution, size and scale through co-located virtual graphics.
FO. 229	shape	Sublimate	Extension of spatial AR with physical shape rendering.
FO. 230	shape	Sublimate	Yoshida et al. use an LCD and lens array to also provide parallax through retro-reflective projection off an arbitrarily shaped bottom surface.
FO. 231	shape	Sublimate	Various projects exploit techniques for moving or displacing physical matter as a means to control and affect physical shapes.
FO. 232	shape	Sublimate	Lumen provides individual control of shape and graphics by varying the height of LED rods using shape-memory alloys, whereas FEELEX employs a flexible screen overlaid on the actuators for a continuous surface, and top-down projection for graphics.
FO. 233	shape	Sublimate	Lumen provides individual control of shape and graphics by varying the height of LED rods using shape-memory alloys, whereas FEELEX employs a flexible screen overlaid on the actuators for a continuous surface, and top-down projection for graphics.
FO. 234	shape	Sublimate	Relief investigates direct manipulation and gestural input to enable interaction techniques that match the capabilities and potential of 2.5D shape displays.
FO. 235	shape	Sublimate	AR-Jig is a 3D-tracked handheld device with a 1D arrangement of linear actuators, for shape deformation and display of virtual geometry, viewable through an AR display.
FO. 236	shape	Sublimate	A common motivation for both AR systems and shape-changing interfaces is to unify virtual and physical representations to enable richer interfaces for viewing and interaction.
FO. 237	shape	Sublimate	An object rendered through this system can rapidly change its visual appearance, physical shape, position, and material properties, such as density.
FO. 238	shape	Sublimate	While such a system does not currently exist and might be physically impossible to build even in the future, we aim at creating interfaces that appear perceptually similar to the user through a mix of actuated shape displays and spatially co-located 3D graphics.
FO. 239	shape	Sublimate	A Sublimate interface renders data as a solid object through a shape display or as spatial 3D graphics through an AR display.
FO. 240	shape	Sublimate	We refer to the transitions from shape output to 3D graphics as "sublimation," and the transition from 3D graphics to shape output as "deposition".

Código	Palavra-chave	Projeto	Palavra-chave em contexto
FO. 241	shape	Sublimate	We refer to the transitions from shape output to 3D graphics as “sublimation,” and the transition from 3D graphics to shape output as “deposition”.
FO. 242	shape	Sublimate	The Sublimate system can render both physical and virtual representations of an object’s shape.
FO. 243	shape	Sublimate	As the modalities of shape output and virtual graphics are synchronized, the system can render an object in either one of them independently, or in both modalities at the same time.
FO. 244	shape	Sublimate	Rendering objects with graphics allows the system to overcome the constraints of physical shapes, for example, when a physical representation would be too large or impractical.
FO. 245	shape	Sublimate	Sublimation can be used to enable virtual controls that are not constrained by the shape display’s degrees of freedom.
FO. 246	shape	Sublimate	Graphical previews are an effective way to inform users of impending shape actuation and can, for example, allow them to cancel or confirm the output in progress.
FO. 247	shape	Sublimate	This can be particularly useful if the generated shape would interact with other physical objects in the space.
FO. 248	shape	Sublimate	A virtually rendered surface can, e.g., materialize when a user approaches it with a finger, and upon proximity with a stylus tool, morph to a flattened shape to better support annotation.
FO. 249	shape	Sublimate	Physical shapes can be used to restrict movement and interaction to permitted areas, or to provide guiding lines for manipulation.
FO. 250	shape	Sublimate	Graphics can help to compensate some of the limitations of current generation shape displays.
FO. 251	shape	Sublimate	They enhance the visual resolution, size and scale of shape output, and augment features a particular type of shape display might not be able to render, such as overhangs.
FO. 252	shape	Sublimate	In addition to transitions between states, many interactions can benefit from the combination of shape output and virtual graphics.
FO. 253	shape	Sublimate	We extend classic AR applications where floating graphics augment physical objects, by also introducing dynamic shape change.
FO. 254	shape	Sublimate	Another application is to overlay alternate versions of an object onto its physical shape in CAD scenarios, similar to “onion skinning” in animation software.
FO. 255	shape	Sublimate	Each setup consists of two main components, a system to render the physical shape output and a display for the spatially co-located 3D graphics.
FO. 256	shape	Sublimate	Physical shapes are rendered through a 2.5D shape display, based on our previously introduced “Relief” system.
FO. 257	shape	Sublimate	Physical shapes are rendered through a 2.5D shape display, based on our previously introduced “Relief” system.
FO. 258	shape	Sublimate	The setup designed for single users renders 3D graphics on a stereoscopic display with a beam splitter, mounted on top of the shape display.
FO. 259	shape	Sublimate	When viewing the physical shape through the beam-splitter with tracked shutter glasses, the graphics appear co-located.
FO. 260	shape	Sublimate	As the display is handheld, it limits user inter-actions with the physical shape display to a single hand.
FO. 261	shape	Sublimate	These different applications demonstrate how objects and interaction elements can transition between physical and digital states, as well as showing how augmented graphics can increase the resolution, fidelity and scale of shape displays, and provide augmented feedback to the user.
FO. 262	shape	Sublimate	The control points of a NURBS (Non-Uniform Rational Basis Spline) surface are represented by individual pins on the shape display.
FO. 263	shape	Sublimate	In that case, the shape display outputs the geometry of the modeled surface instead of the control points and the user can feel the physical deformation.

Código	Palavra-chave	Projeto	Palavra-chave em contexto
FO. 264	shape	Sublimate	Volumetric data sets are rendered as 3D graphics that are spatially co-located with a physical shape in this application.
FO. 265	shape	Sublimate	The physical shape represents the bounds of the volume ray casting algorithm and can be reshaped by the user to create a non-planar cross section through the volume.
FO. 266	shape	Sublimate	The physical shape represents the bounds of the volume ray casting algorithm and can be reshaped by the user to create a non-planar cross section through the volume.
FO. 267	shape	Sublimate	This interaction is similar to Phoxel Space, but has the advantages of an actuated shape display, such as being able to save and load cross sections, or to define parametric shapes.
FO. 268	shape	Sublimate	This interaction is similar to Phoxel Space, but has the advantages of an actuated shape display, such as being able to save and load cross sections, or to define parametric shapes.
FO. 269	shape	Sublimate	The cross section can be conveniently flattened and moved computationally, while the user can intervene at any time by modifying its shape by hand.
FO. 270	shape	Sublimate	While solid models are rendered on the physical shape display and can be touched and manipulated by the user, wind flow is displayed through spatially co-located 3D graphics.
FO. 271	shape	Sublimate	The virtual wind tunnel shows the advantages of augmenting shape displays with virtual graphics, and having bi-directional control of the output.
FO. 272	shape	Sublimate	In this application scenario, the shape display renders physical terrain, while several tablet computers can be used to simultaneously interact and augment the physical surface.
FO. 273	shape	Sublimate	Users can adjust the region of interest of the map rendered on the shape display by using pan and zoom touch gestures on the tablet interface.
FO. 274	shape	Sublimate	Moreover, individual users may display additional data overlays visible through their tablets, which align with the captured image of the shape display taken from the tablet's camera.
FO. 275	shape	Sublimate	Our single-user setup consists of a 2.5D shape display and a co-located semi-transparent 3D display.
FO. 276	shape	Sublimate	The shape display is based on a hardware setup similar to Relief, consisting of a table with 120 motorized pins extruding from the tabletop.
FO. 277	shape	Sublimate	The shape display is controlled by a 2010 Mac Mini, which communicates with the application PC through OpenSoundControl (OSC).
FO. 278	shape	Sublimate	A custom OF application tracks visual markers placed around the shape display using the Qualcomm Vuforia API.
FO. 279	shape	Sublimate	After computing the screen position relative to the shape output, the video view is overlaid with adjusted 3D graphics.
FO. 280	shape	Sublimate	The shape display is augmented with projection onto the object surface to enhance appearance and provide graphical feedback when viewing the shape without the iPad.
FO. 281	shape	Sublimate	The shape display is augmented with projection onto the object surface to enhance appearance and provide graphical feedback when viewing the shape without the iPad.
FO. 282	shape	Sublimate	The shape display is controlled by a 2010 Mac Mini, which communicates with the application computer through OSC.
FO. 283	shape	Sublimate	To evaluate the Sublimate system, we conducted a user study to measure the advantages of shape output combined with spatial graphics.
FO. 284	shape	Sublimate	We investigate how interacting with spatial AR without haptic feedback compares to spatial AR with co-located shape output, and to spatial AR with single-point haptic interaction.
FO. 285	shape	Sublimate	Haptic feedback provided by shape output is advantageous compared to mid-air interaction with only virtual graphics.

Código	Palavra-chave	Projeto	Palavra-chave em contexto
FO. 286	shape	Sublimate	We collected informal and anecdotal data from users on how well they felt that the virtual graphics aligned with the shape display, the perceived effective difference between virtual or physical rendering when viewed, and general ease of use.
FO. 287	shape	Sublimate	As highlighted in, few user evaluations of shape displays exist and we believe that an important first step is to quantify the advantages of direct interaction with shape displays coupled with virtual graphics.
FO. 288	shape	Sublimate	As highlighted in, few user evaluations of shape displays exist and we believe that an important first step is to quantify the advantages of direct interaction with shape displays coupled with virtual graphics.
FO. 289	shape	Sublimate	We ran our study using the see-through AR version of Sublimate as it provides for higher accuracy matching of graphics and shape output, while leaving two hands free for input.
FO. 290	shape	Sublimate	For physical input and output we made use of the shape display's physical pins.
FO. 291	shape	Sublimate	In the conditions where the participants manipulated the physical shape display manually, each of the vertices was rendered physically by the height of the pin, and virtual graphics displayed edges connecting the pins...
FO. 292	shape	Sublimate	The actuated shape display was designed for two-handed pin manipulation, and that is the dominant method of input using the shape display; therefore we argue that this study validates the hypothesis that the shape display can perform better than a mid-air 3D pointing device.
FO. 293	shape	Sublimate	The actuated shape display was designed for two-handed pin manipulation, and that is the dominant method of input using the shape display; therefore we argue that this study validates the hypothesis that the shape display can perform better than a mid-air 3D pointing device.
FO. 294	shape	Sublimate	The actuated shape display was designed for two-handed pin manipulation, and that is the dominant method of input using the shape display; therefore we argue that this study validates the hypothesis that the shape display can perform better than a mid-air 3D pointing device.
FO. 295	shape	Sublimate	This concern of pin obstruction has been previously discussed and may be one of the key limitations of manipulating and interacting with physical shape displays, which may be addressed through different interaction techniques.
FO. 296	shape	Sublimate	"Two-handed inter-action felt the most natural. I felt like I was molding the pins into shape"
FO. 297	shape	Sublimate	One effect of the shape display is that users were more surprised when the shape display cleared all of the pins, than in the virtual case.
FO. 298	shape	Sublimate	One effect of the shape display is that users were more surprised when the shape display cleared all of the pins, than in the virtual case.
FO. 299	shape	Sublimate	This is a possible limitation of sublimation-based interaction techniques, where the physical shape changes quickly.
FO. 300	shape	Sublimate	While our study focused on evaluating direct manipulation on 2.5D shape displays with co-located augmented graphics, we believe that results will be similar using different shape display hardware.
FO. 301	shape	Sublimate	While our study focused on evaluating direct manipulation on 2.5D shape displays with co-located augmented graphics, we believe that results will be similar using different shape display hardware.
FO. 302	shape	Sublimate	Even with very limited shape display hardware, there are positive results that show that these type of interfaces can perform better than freehand gesture in certain cases.

Código	Palavra-chave	Projeto	Palavra-chave em contexto
FO. 303	shape	Sublimate	Other interaction techniques would have to be developed to allow a 2.5D shape display to manipulate a 3D mesh, and the wand input clearly has more degrees of freedom, which can easily be mapped to that interaction.
FO. 304	shape	Sublimate	However, we believe that there are many new interaction techniques to be developed for shape display interfaces and new hardware configurations that can improve their performance.
FO. 305	shape	Sublimate	The current Sublimate system relies on a 2.5D actuated shape display to render the physical objects.
FO. 306	shape	Sublimate	Current 2.5D actuated shape displays have limited spatial resolution, haptic resolution, refresh rate and degrees of freedom, in comparison to other haptic input devices.
FO. 307	shape	Sublimate	In our future work, we would like to explore implementing Sublimate interactions with other actuated tangible interfaces and shape displays beyond Relief.
FO. 308	shape	Sublimate	We have presented Sublimate, our vision of how 3D spatial graphics and physical shape output can be combined, and we highlight the potential in computational transitions between these states.
FO. 309	shape	Sublimate	Our single-user system has a spatial optical see-through display for co-located high-resolution graphics and shape output, while our multi-user system employs handheld tablet-based AR.
FO. 310	shape	Sublimate	Sublimate can provide novel interactions for 3D data, allow for switchable control between precise physical manipulation and mid-air gesture, provide physical affordances on demand, and extend the shape display's resolution and scale.
FO. 311	shape	Sublimate	A formal user evaluation showed that bimanual interaction with spatial 3D graphics through the shape display can outperform mid-air interaction with a wand.
FO. 312	shape	Sublimate	We believe that the intersection between physical shape output and spatial graphics is a rich area of exploration, and that the state transitions described here can be a valuable avenue for further investigation.
FO. 313	shape	PneUI	This paper presents PneUI, an enabling technology to build shape-changing interfaces through pneumatically-actuated soft composite materials.
FO. 314	shape	PneUI	The composite materials integrate the capabilities of both input sensing and active shape output.
FO. 315	shape	PneUI	The shape changing states are computationally controllable through pneumatics and pre-defined structure.
FO. 316	shape	PneUI	We explore the design space of PneUI through four applications: height changing tangible phicons, a shape changing mobile, a transformable tablet case and a shape shifting lamp.
FO. 317	shape	PneUI	We explore the design space of PneUI through four applications: height changing tangible phicons, a shape changing mobile, a transformable tablet case and a shape shifting lamp.
FO. 318	shape	PneUI	Hard bodies with construction of rigid structural and electronic elements have limited the form, function and interaction of shape changing interfaces in HCI.
FO. 319	shape	PneUI	Thus a range of technologies in HCI have been developed to enable soft and organic interfaces, including flexible sensing techniques, dynamic stiffness, texture and buttons on malleable surfaces, soft deformable surface output, and 2.5D shape display with elastic covers.
FO. 320	shape	PneUI	...we take a holistic view of the material itself and envision a composite material that integrates input sensing and active shape output.
FO. 321	shape	PneUI	Materials with different mechanical properties can be combined to form separate structural layers for the soft composites, which can be utilized to create shape changing interfaces without rigid mechanical elements.



Código	Palavra-chave	Projeto	Palavra-chave em contexto
FO. 322	shape	PneUI	In this paper, we presented PneuUI, pneumatically actuated soft composite materials, that follow three principles: 1) the shape output is computationally controllable through pneumatics and pre- defined structure...
FO. 323	shape	PneUI	...3) the material should integrate both input sensing and active shape output.
FO. 324	shape	PneUI	Examples of utilizing shape changing primitives for HCI applications are illustrated in Figure 1.
FO. 325	shape	PneUI	We then talk about the layered structures of soft composite materials and explain the composites' active shape output and input sensing capabilities in separate chapters.
FO. 326	shape	PneUI	Creation of pneumatically actuated soft composite materials, which integrates both input sensing and active shape output.
FO. 327	shape	PneUI	Primitives of soft shape changing at both macro and micro scales, including curvature change of surfaces, unidirectional volume change of solid geometries, and dynamic texture change.
FO. 328	shape	PneUI	Development of two techniques that embed sensing into composite material and interfaces: 1) conductive pads composited on structural layers for sensing shape output and gestural input using capacitive and electric field sensing...
FO. 329	shape	PneUI	In contrast to other techniques for shape change, such as spatial arrangement of actuated modules, self-foldable chains, self-foldable surfaces, soft robotics often focuses on pneumatic actuation of elastomeric channels and bladders.
FO. 330	shape	PneUI	While a primary focus of soft robotics is the improvement of the robot's performance and the exploration of the bio-inspired mechanism itself, there is a large space to introduce soft robotic technology in constructing shape changing interfaces.
FO. 331	shape	PneUI	The exploration of Shape Changing User Interfaces in HCI is still in its infancy, as techniques for shape change, flexible sensing and interaction techniques are being developed.
FO. 332	shape	PneUI	The exploration of Shape Changing User Interfaces in HCI is still in its infancy, as techniques for shape change, flexible sensing and interaction techniques are being developed.
FO. 333	shape	PneUI	Shape-Changing Mobiles are actuated by RC servo motors to provide tapering of the back of the mobile phone.
FO. 334	shape	PneUI	Those rigid mechanisms can achieve controllable transformations, yet not compliant, making it hard for these systems to conform to intricate shapes and limiting the amount of possible shape change states.
FO. 335	shape	PneUI	Those rigid mechanisms can achieve controllable transformations, yet not compliant, making it hard for these systems to conform to intricate shapes and limiting the amount of possible shape change states.
FO. 336	shape	PneUI	Shape memory alloy (SMA) based actuators have been used to bend surfaces.
FO. 337	shape	PneUI	In the field of HCI, pneumatic inflation has also been explored as an approach for shape change.
FO. 338	shape	PneUI	Inflatable Mouse is a shape-shifting mouse that can change the volume by using an air balloon and a built-in pump.
FO. 339	shape	PneUI	Granular jamming, which can also be controlled pneumatically, can provide malleable surface with adjustable stiffness, and allows for passive shape change.
FO. 340	shape	PneUI	In contrast to jamming, this work focuses on pneumatic actuation – allowing for active shape change.
FO. 341	shape	PneUI	The types of shape change in HCI have been categorized as: orientation, form, volume, texture, viscosity, spatiality, adding/subtracting and permeability.
FO. 342	shape	PneUI	We chose to focus on curvature, volume and texture as shape change primitives because we believe those encompass a large space of shape change in mobile and tangible applications, as demonstrated by past work.

Código	Palavra-chave	Projeto	Palavra-chave em contexto
FO. 343	shape	PneUI	We chose to focus on curvature, volume and texture as shape change primitives because we believe those encompass a large space of shape change in mobile and tangible applications, as demonstrated by past work.
FO. 344	shape	PneUI	Pneumatic soft composites provide many opportunities for designing significant and novel applications for HCI, primarily as an enabling technology for shape changing user interfaces.
FO. 345	shape	PneUI	Shape change can be used to convey information to the user about computational state and provide dynamic affordances.
FO. 346	shape	PneUI	Shape change, both at the macro and micro level, can be used to convey computational states to users as a type of display.
FO. 347	shape	PneUI	For example, smaller scale shape change, which we call texture change, has previously been shown to enable a separate haptic channel for representing or communicating information.
FO. 348	shape	PneUI	A shape changing iPad case is introduced in the paper as an example of dynamic textures.
FO. 349	shape	PneUI	Shape change can also provide new ways for users to interact with devices on demand.
FO. 350	shape	PneUI	In addition to dynamic physical affordances, adaptable shapes can increase economic performance for specific tasks.
FO. 351	shape	PneUI	We develop a prototype of mobile phone that can change shape and motion for different use cases.
FO. 352	shape	PneUI	The first three are input modalities, and the last one is shape output.
FO. 353	shape	PneUI	A system of shape changing tangible phicons is developed to demonstrate different gesture sensing modalities.
FO. 354	shape	PneUI	One structural layer utilizes an elastomeric polymer (or elastomer) as the main material to enable isotropic shape deformation.
FO. 355	shape	PneUI	Finally an add-on layer can be composited to control other material properties other than active shape output.
FO. 356	shape	PneUI	For example, Jamming particles can control surface stiffness to give haptic affordances or lock shapes in a certain state...
FO. 357	shape	PneUI	For example, placing electrodes onto 3D substrates enables sensing the 3D shape output through changes in capacitance.
FO. 358	shape	PneUI	The choice of materials is driven both by the type of shape change we want to achieve and also materials that we think other researchers would have ready access to, so as to make our work more accessible.
FO. 359	shape	PneUI	By introducing a greater variety of energy sources, we could composite additional ranges of active materials, such as heat-driven shape memory alloys and thermoplastics.
FO. 360	shape	PneUI	We choose curvature, volume and texture to explore how soft pneumatic composite materials provide a range of deformation behaviors and thus enable or enhance shape changing interfaces on both the macro and micro level.
FO. 361	shape	PneUI	Laying out the crease lines diagonally (Figure 6f) generates helical shapes instead of curling on a single plane (Figure 6e).
FO. 362	shape	PneUI	To apply the aforementioned approaches of dynamic control of shape changing states, we test how specifically designed crease patterns and respective control of airbags can make a flat circular shape morph into different spatial structures with three stands (Figure 7a).
FO. 363	shape	PneUI	To apply the aforementioned approaches of dynamic control of shape changing states, we test how specifically designed crease patterns and respective control of airbags can make a flat circular shape morph into different spatial structures with three stands (Figure 7a).
FO. 364	shape	PneUI	The cause of shape deformation can be air or human gestures.
FO. 365	shape	PneUI	We perceive the change of texture as a local and micro level shape changing behavior occurring on the surface.

Código	Palavra-chave	Projeto	Palavra-chave em contexto
FO. 366	shape	PneUI	Further, through the application of shape shifting lamp, we have also demonstrated the possibility of compositing rigid electrical components, such as surface mounted LEDs, within soft bodies.
FO. 367	shape	PneUI	We build four prototypes to explore the potential of shape changing interfaces enabled by the soft composite material.
FO. 368	shape	PneUI	The shape changing mobile is a flexible body that enables multiple bending states, to give users dynamic affordances for various use cases.
FO. 369	shape	PneUI	It can morph from a bar shape to a curved phone shape if a user answers the phone call; when placed over the user's arm, it turns into a wearable wristband (Figure 19).
FO. 370	shape	PneUI	It can morph from a bar shape to a curved phone shape if a user answers the phone call; when placed over the user's arm, it turns into a wearable wristband (Figure 19).
FO. 371	shape	PneUI	The fabrication of the shape changing mobile is based on one type of the aforementioned primitives: curvature change on surfaces.
FO. 372	shape	PneUI	The construction is based on linear elongation of shape changing primitives.
FO. 373	shape	PneUI	This prototype demonstrates the hybrid of macro and micro level shape change, based on the isotropic deformation behavior exhibited by homogeneous elastomer.
FO. 374	shape	PneUI	This lamp supports large deformation from a straight strip shape to a rounded bulb shape.
FO. 375	shape	PneUI	This lamp supports large deformation from a straight strip shape to a rounded bulb shape.
FO. 376	shape	PneUI	This demonstrates Shape-changing combined with optical properties (Figure 22).
FO. 377	shape	PneUI	The construction of the lamp is inspired by one type of shape changing primitives: the curling behavior under curvature change on surfaces.
FO. 378	shape	PneUI	Soft lithography is adapted for fabricating the shape-shifting lamp.
FO. 379	shape	PneUI	The current fabrication process allows the interfaces to morph between two shapes, by designing certain structure layers that composite with airbags.
FO. 380	shape	PneUI	It is still desired that the interface can have multiple shape-changing states that can be dynamically controlled in real-time.
FO. 381	shape	PneUI	For example, by embedding memory alloy or heat reactive polymers, and combining two actuation sources (air and heat respectively), we might be able to achieve more flexible control of shape changing states.
FO. 382	shape	PneUI	This is a step closer towards programmable, dynamically controllable, shape changing interfaces.
FO. 383	shape	PneUI	Other types of shape changing behaviors are yet to be explored systematically.
FO. 384	shape	PneUI	A broader and systematic exploration of shape changing primitives could increase use cases in the design of shape changing interfaces
FO. 385	shape	PneUI	A broader and systematic exploration of shape changing primitives could increase use cases in the design of shape changing interfaces
FO. 386	shape	PneUI	Shape locking is currently implemented with solenoid switches.
FO. 387	shape	PneUI	However, stiffness changing materials, such as Jamming particles, can be adapted to lock shapes or introduce dynamic constraints.
FO. 388	shape	PneUI	However, stiffness changing materials, such as Jamming particles, can be adapted to lock shapes or introduce dynamic constraints.
FO. 389	shape	PneUI	We have presented various types of shape-changing interface enabled by pneumatic soft composite materials.

Código	Palavra-chave	Projeto	Palavra-chave em contexto
FO. 390	shape	PneUI	We demonstrated shape-changing primitives, and present a framework and test results of the selection of materials, structures, soft fabrication processes, and pneumatic control systems to construct soft composite materials.
FO. 391	shape	PneUI	This approach creates new opportunities to employ shape-changing interfaces by using responsive materials.
FO. 392	shape	jamSheets	Interfaces that exhibit tunable stiffness properties can yield dynamic haptic feedback and shape deformation capabilities.
FO. 393	shape	jamSheets	Recently, researchers have explored advanced technology to dynamically control material properties like shape and stiffness.
FO. 394	shape	jamSheets	Shape-changing interfaces investigate dynamic interaction that derives from actively changing forms, to build more responsive physical interfaces.
FO. 395	shape	jamSheets	In this paper, we look into sheet shaped material.
FO. 396	shape	jamSheets	In everyday life we frequently encounter sheet shaped material, since various raw materials, such as metal, wood, and plastic, are vastly available in sheet.
FO. 397	shape	jamSheets	The ability to reconfigure the stiffness enables novel interactions for sheet shaped material.
FO. 398	shape	jamSheets	In addition to robotic manipulator, layer jamming has been used for orthosis and protective equipment that can be shaped and fitted to the body in an optimal way have also been developed.
FO. 399	shape	jamSheets	In this research, both hydraulic and pneumatic systems are implemented for use cases such as tunable clay, a transparent haptic lens and ShapePhones.
FO. 400	shape	jamSheets	This work demonstrates the large potential of utilizing jamming techniques to construct flexible, free-formed and tunable-stiffness displays and shapes.
FO. 401	shape	jamSheets	ClaytrixSurface is another example of a pneumatic jamming tabletop interface, which enables optical shape sensing through a ceiling-mounted depth-sensing camera.
FO. 402	shape	jamSheets	For thin sheets, shape memory alloys, Electroactive Polymers (EAP), electromagnets and air bladders are among widely used external actuators.
FO. 403	shape	jamSheets	Traditionally, locking structures are required for maintaining a solid shape in origami.
FO. 404	shape	jamSheets	Layer-jamming with crease patterns can help to solidify the shape without additional locking structures.
FO. 405	shape	jamSheets	In our material samples, pressure sensors are constructed as round shapes and can be attached to any area that need pressure detection.
FO. 406	shape	jamSheets	Bending sensors are constructed in rectangular shapes and can be attached to the hinges at which bending needs to be detected (Figure 4d-f).
FO. 407	shape	jamSheets	We sequentially project three material textures (wood, foam and leather) on a layer-jamming unit, which is shaped like a tablet.
FO. 408	shape	jamSheets	The system will freeze the deformed shape.
FO. 409	shape	jamSheets	When users transform the flat sheet into the shape of a chair by creating two folds where the sensors are embedded, the system will automatically start the jamming process after three seconds
FO. 410	shape	jamSheets	Once jammed, the carpet will become stiff enough to maintain the chair shape and support up to a load of up to 55 kilograms.
FO. 411	shape	jamSheets	The carpet can be formed into other 3D shapes as well, such as a table board, or a free-formed lounge.
FO. 412	shape	jamSheets	Jamming the surface will maintain the actuated shapes.
FO. 413	shape	jamSheets	Afterwards, the inflated bladders can be deflated while the table shape is maintained.
FO. 414	shape	jamSheets	To detect the shape and orientation of the display, and also to avoid the noise from users' hand occlusion, we utilized depth sensing with a depth camera mounted on top of the display.

Código	Palavra-chave	Projeto	Palavra-chave em contexto
FO. 415	shape	jamSheets	By embedding further computational capabilities into the jamming system, we can explore multimodal interaction with the material, and enable “memory” of its own shape to the material.
FO. 416	shape	jamSheets	After the chair is unjammed and returns flat, users can say, “replay,” to recall the saved shape via the structure’s self-actuation capabilities.
FO. 417	shape	jamSheets	We see layer jamming as a highly useful technique for shape-changing user interfaces and products. It is one step further towards the vision of Radical Atoms.
FO. 418	shape	OptiElastic	We introduce the design and fabrication process of integrating optical fiber into pneumatically driven soft composite shape changing interfaces.
FO. 419	shape	OptiElastic	Embedded optical waveguides can provide both sensing and illumination, and add one more building block to the design of designing soft pneumatic shape changing interfaces.
FO. 420	shape	OptiElastic	Our main contribution is: integration of optical waveguides into pneumatic shape changing interfaces to allow for shape and interaction sensing as well as general illumination and pixel displaying...
FO. 421	shape	OptiElastic	Our main contribution is: integration of optical waveguides into pneumatic shape changing interfaces to allow for shape and interaction sensing as well as general illumination and pixel displaying...
FO. 422	shape	OptiElastic	Our goal is to leverage previous work in the context of pneumatic shape changing interfaces.
FO. 423	shape	OptiElastic	Rather than breaking new ground in the field of using optical fibers for displays in general, we try to demonstrate how broad and powerful the existing techniques are in the context of elastomer based shape changing UIs.
FO. 424	shape	OptiElastic	By casting a clear silicone with a predefined shape into another translucent silicone, we can make the translucent part illuminated through light scattering.
FO. 425	shape	LineFORM	In this paper we explore the design space of actuated curve interfaces, a novel class of shape changing-interfaces.
FO. 426	shape	LineFORM	By utilizing such aspects of lines and curves, together with the added capability of shape-change, new possibilities for display, interaction, and body constraint are possible.
FO. 427	shape	LineFORM	To motivate this work we present applications such as shape changing cords, mobiles, body constraints, and data manipulation tools.
FO. 428	shape	LineFORM	There are rich possibilities for inter- action through curve based interfaces, however we believe they must also be tightly coupled with shape output to allow for richer interaction.
FO. 429	shape	LineFORM	Researchers have recently explored the use of shape change to convey information and to provide dynamic affordances for interaction.
FO. 430	shape	LineFORM	However these explorations have mainly focused on shape changing surfaces, volumes, and actuated tabletop robots.
FO. 431	shape	LineFORM	The use of shape-changing curves or chains has not been explored in detail in HCI, but it is fundamental in biology and robotics.
FO. 432	shape	LineFORM	Researchers in robotics have been inspired by protein folding and have proposed theories and built prototypes of a chain-based robotic systems which can reconfigure into any shape.
FO. 433	shape	LineFORM	LineFORM can physically display expressive 2D and 3D shapes, both for information representation and for dynamic affordances.
FO. 434	shape	LineFORM	Researchers in the field of shape-changing interfaces have investigated how to move beyond physical input, such as those demonstrated in the curve based input devices, to more active interfaces which use physical shape and form as an output medium.

Código	Palavra-chave	Projeto	Palavra-chave em contexto
FO. 435	shape	LineFORM	Researchers in the field of shape-changing interfaces have investigated how to move beyond physical input, such as those demonstrated in the curve based input devices, to more active interfaces which use physical shape and form as an output medium.
FO. 436	shape	LineFORM	Many different topologies for shape-changing interfaces have been explored ranging from actuated points, surfaces, solids and modular robots.
FO. 437	shape	LineFORM	Towards the goal of programmable matter, other researchers have explored the abilities of this class of robots to create different shapes, similarly to how proteins can fold into complex patterns.
FO. 438	shape	LineFORM	Here we describe the design space and interaction potential of actuated curves for shape changing UIs.
FO. 439	shape	LineFORM	Also, curves have the capability to represent not only 2D or 3D curves, but also a single continuous curve can be bent and shaped to form surfaces and solid-based shapes.
FO. 440	shape	LineFORM	Also, curves have the capability to represent not only 2D or 3D curves, but also a single continuous curve can be bent and shaped to form surfaces and solid-based shapes.
FO. 441	shape	LineFORM	We can represent both static shape and dynamic continuous motion with the interface based on the 3 types of shapes as above.
FO. 442	shape	LineFORM	We can represent both static shape and dynamic continuous motion with the interface based on the 3 types of shapes as above.
FO. 443	shape	LineFORM	Physical Icons can be displayed, such as the shape of a phone when there is an incoming call, see Figure 1 d.
FO. 444	shape	LineFORM	For example, a mobile actuated curve interface could change from the shape of game controller, enabled by touch sensors, to a wrist watch for different applications or settings.
FO. 445	shape	LineFORM	The changes in the shape of the actuated curve interface can apply forces to the users hands or body to provide haptic feedback.
FO. 446	shape	LineFORM	Physical curves have a number of inherent affordances and we interact with curved shaped objects (string, cord, wire) in daily life.
FO. 447	shape	LineFORM	Changes to the shape of the curve can be reflected in the digital model which the curve renders.
FO. 448	shape	LineFORM	With its thin shaped form, line shaped interfaces provide affordance of pinching
FO. 449	shape	LineFORM	With its thin shaped form, line shaped interfaces provide affordance of pinching
FO. 450	shape	LineFORM	Beyond input alone, actuated curves can use their shape output to provide active physical feedback to the user as they interact with it.
FO. 451	shape	LineFORM	Actuated curve interfaces can also provide haptic feedback to users by changing its own shape as it is being interacted with, for example simulating haptic detents as the user bends a section.
FO. 452	shape	LineFORM	Actuated curve interfaces can constrain kinetic motion of the body by changing its shape and stiffness while in contact or worn by a user.
FO. 453	shape	LineFORM	Shape Memory Alloys are light but relatively weak and hard to back drive.
FO. 454	shape	LineFORM	A second smaller and higher resolution LineFORM focuses on shape display in 2D for mobile and cord based interaction.
FO. 455	shape	LineFORM	By controlling the angle of each servo motor with a microcontroller, the interface can change its overall shape.
FO. 456	shape	LineFORM	Our higher level control for the overall shape and motion is based on fitting a curve to a shape.
FO. 457	shape	LineFORM	Our higher level control for the overall shape and motion is based on fitting a curve to a shape.
FO. 458	shape	LineFORM	In the case of creating shape data from iconic data, we extract outline from binary image data as series of vectors...

Código	Palavra-chave	Projeto	Palavra-chave em contexto
FO. 459	shape	LineFORM	In addition, we can also load in previously recorded shape data from either deforming LineFORM directly by hand...
FO. 460	shape	LineFORM	This application demonstrates how the shape-changing interface can be integrated with a line-shaped everyday object, cord.
FO. 461	shape	LineFORM	This application demonstrates how the shape-changing interface can be integrated with a line-shaped everyday object, cord.
FO. 462	shape	LineFORM	For instance, when it is connected to a lamp module, it changes the shape to stand/shade for lamp and forms an input lever to enable the user to control the brightness.
FO. 463	shape	LineFORM	LineFORM can be used as a shape-changing ruler to support user drafting and drawing by providing a curve to draw lines along it or a boundary to define a region to fill within it, see Figure 10.
FO. 464	shape	LineFORM	It can change from a straight line, to a sinusoidal curve, and a variety of other shapes.
FO. 465	shape	LineFORM	Users can freely modify the model through direct deformation of its shape, or in another mode the curve remains stiff until a user pinches individual joints to loosen their stiffness.
FO. 466	shape	LineFORM	Direct manipulation and shape output can be combined to create various interaction techniques such as rendering hinges (change the stiffness on specific segments to enable users to partially deform), mirroring (detect deformation on one side to make symmetrical deformation on the other side), and snapping to grid (the line automatically snap to certain angles after users manipulate it roughly)...
FO. 467	shape	LineFORM	To represents smoother lines, other actuation technologies which have organic shape transformation can be considered (pneumatic, SMA, etc.).
FO. 468	shape	LineFORM	When replicating 3D shapes, there are obvious technical implications of torque and weight trade offs.
FO. 469	shape	LineFORM	Another approach would be to submerge actuated curve interfaces in a fluid and make them neutrally buoyant - this would limit the contexts for interaction, but might allow a larger range of 3D shapes to be created.
FO. 470	shape	LineFORM	Predicting the collision between servomotors according to the input shape data, and optimising the final shape is also needed.
FO. 471	shape	LineFORM	Predicting the collision between servomotors according to the input shape data, and optimising the final shape is also needed.
FO. 472	shape	LineFORM	Also the length of the interface might always be a limitation of how complex and large the shapes are that it can replicate.
FO. 473	shape	LineFORM	...however we feel that inter-material interaction (interacting with physical objects) has interesting directions from the perspective of interaction design, because we daily use line-shaped objects to manipulate other physical objects; to bundle, connect, or hang.
FO. 474	shape	LineFORM	In addition it might be useful to combine actuated curve interfaces with other shape output interfaces such as tangible tabletop robots
FO. 475	shape	LineFORM	In this paper we explored a new category of shape-changing interfaces which are based on linear series of actuators.
FO. 476	shape	LineFORM	In contrast to other grounded shape-changing interfaces such as shape displays, actuated curve displays can have a much greater change in scale...
FO. 477	shape	LineFORM	In contrast to other grounded shape-changing interfaces such as shape displays, actuated curve displays can have a much greater change in scale...
FO. 478	shape	LineFORM	We also hope to evaluate interaction with actuated curve interfaces and compare with other form factors for shape-changing interfaces.

Código	Palavra-chave	Projeto	Palavra-chave em contexto
FO. 479	shape	LineFORM	...a relatively small number of actuators can be used to achieve an expressive display, and these systems may be easier to prototype than other form factors of high resolution shape display.
FO. 480	shape	bioLogic	On the other hand, in the field of Human-Computer Interaction (HCI), material-based interface design and shape-change interfaces are emerging topics.
FO. 481	shape	bioLogic	With biofilm as the basic building blocks, we design responsive structures and transformations, which can be referenced when we try to achieve a certain shape change in the design of HCI systems.
FO. 482	shape	bioLogic	Then, we look into the database and obtain the shape of each basic curve through the interpolation of the existing data.
FO. 483	shape	bioLogic	Those curves are then connected to achieve a rough shape of our model.
FO. 484	shape	bioLogic	In order to mimic the natural flower changing shape and color at the same time, we mix thermochromic paint into liquid latex and produce our own color-changing film substrate.
FO. 485	shape	bioLogic	A flower bouquet is designed to transform in both shape and color.
FO. 486	shape	bioLogic	Kempaiah and Nie have published a review paper summarizing recent progress of shape transformation using soft materials.
FO. 487	shape	bioLogic	Beyond common electric motors, many more types of actuations have been adapted to design shape changing interfaces: Pneumatic actuation, shape memory alloy, piezo actuators, jamming material, ferromagnetic fluids, etc.
FO. 488	shape	bioLogic	Beyond common electric motors, many more types of actuations have been adapted to design shape changing interfaces: Pneumatic actuation, shape memory alloy, piezo actuators, jamming material, ferromagnetic fluids, etc.
FO. 489	shape	bioLogic	Different techniques have their unique benefits: fast prototyping (electric motors), big force and compliant to malleable surfaces (pneumatic actuators), silent and flexible (shape memory alloy), phase transition (ferromagnetic fluids).
FO. 490	shape	bioLogic	Materiality/matter based interface design and shape changing interfaces are emerging topics in HCI that are gaining more and more attention.
FO. 491	shape	bioLogic	For example, we can design shape-change interfaces that grow.
FO. 492	shape	bioLogic	For example, shape changing food that indicates when the temperature is right for eating.
FO. 493	shape	bioLogic	As designing shape-change interfaces draw more and more attention in HCI, materiality becomes one of the important aspects we need to be concerned with in design.
FO. 494	shape	uniMorph	Researchers have been investigating shape-changing interfaces, however technologies for thin, reversible shape change remain complicated to fabricate.
FO. 495	shape	uniMorph	Researchers have been investigating shape-changing interfaces, however technologies for thin, reversible shape change remain complicated to fabricate.
FO. 496	shape	uniMorph	uniMorph is an enabling technology for rapid digital fabrication of customized thin-film shape-changing interfaces.
FO. 497	shape	uniMorph	By combining the thermo-electric characteristics of copper with the high thermal expansion rate of ultra-high molecular weight polyethylene, we are able to actuate the shape of flexible circuit composites directly.
FO. 498	shape	uniMorph	The shape-changing actuation is enabled by a temperature driven mechanism and reduces the complexity of fabrication for thin shape-changing interfaces.
FO. 499	shape	uniMorph	The shape-changing actuation is enabled by a temperature driven mechanism and reduces the complexity of fabrication for thin shape-changing interfaces.



Código	Palavra-chave	Projeto	Palavra-chave em contexto
FO. 500	shape	uniMorph	We present composites that are actuated by either environmental temperature changes or active heating of embedded structures and provide a systematic overview of shape-changing primitives
FO. 501	shape	uniMorph	The use of this new dimension for input possibilities has been explored in several papers, however there is considerably fewer work on active shape output for this medium
FO. 502	shape	uniMorph	One of the barriers to further research in this field is the complicated and expensive fabrication processes required to create shape-changing material mechanics.
FO. 503	shape	uniMorph	Current shape-changing interfaces either rely on external rigid printed circuit boards (PCBs) or embedded flexible printed circuits (FPCs) designed for and fitted to the shape-changing medium.
FO. 504	shape	uniMorph	Current shape-changing interfaces either rely on external rigid printed circuit boards (PCBs) or embedded flexible printed circuits (FPCs) designed for and fitted to the shape-changing medium.
FO. 505	shape	uniMorph	Shape-changing flexible circuits have been shown in robotic works, however the presented composites are either non-reversible one-time actuation or impossible to reproduce with common lab devices.
FO. 506	shape	uniMorph	The shape-changing actuation is enabled by a temperature driven mechanism, similar to bi-metal strips and dramatically reduces the complexity of fabrication.
FO. 507	shape	uniMorph	This enables more HCI researchers to design and fabricate thin-film shape-changing interfaces.
FO. 508	shape	uniMorph	In this paper we present uniMorph, a thin-film composite for rapid fabricating of shape-changing interfaces.
FO. 509	shape	uniMorph	Design and fabrication of thin shape-changing composites with embedded sensing, control architecture and active shape output.
FO. 510	shape	uniMorph	Primitives of uniMorph shape-changing which includes curvature change of surfaces; controlled hinging and assembly of 3D structures; programming of neutral state of the material.
FO. 511	shape	uniMorph	Recent interest in new form factors and shape changing interfaces has brought an advent of flexible printed circuits (FPCs).
FO. 512	shape	uniMorph	HCI projects like Gummi, Paperphone and Snaplet show how shape sensing can be integrated with flexible circuit sheets without sacrificing the flexibility of the material.
FO. 513	shape	uniMorph	The OUI movement is led by the idea that the physical shape of objects and displays will and should deviate from its current flat static form and become as malleable as the pixels on a screen.
FO. 514	shape	uniMorph	This transformation is powered by transitive materials that sense and conform to the users molding and actively drive its own shape-change.
FO. 515	shape	uniMorph	For thin sheet materials with active shape-change, techniques include soft user interfaces actuated by air pressure as well as flexible mobile devices driven by nitinol.
FO. 516	shape	uniMorph	The field of robotics is primarily concerned with the structural assembly of robots or sensors, as well as developing new techniques for creating stronger and faster shape-changing materials.
FO. 517	shape	uniMorph	In this paper, we are focused on making shape-changing techniques available to the HCI field.
FO. 518	shape	uniMorph	We leverage existing techniques like joule heating with copper, and combine it with cheap, accessible, and easy to fabricate materials to create a shape-changing composite and fabrication method that is reproducible for HCI researchers.

Código	Palavra-chave	Projeto	Palavra-chave em contexto
FO. 519	shape	uniMorph	In contrast with other electromechanical methods for self-assembly, self-folding robotics focuses on shape actuation material actuation mechanisms instead of motors or other external devices.
FO. 520	shape	uniMorph	Previous work on reversible material shape actuation for sheets using nitinol and electroactive polymers is impossible to reproduce without expensive equipment.
FO. 521	shape	uniMorph	Piezoelectric actuators can be found in the same thin-sheet form factor, but have drawbacks that make them impractical for shape-changing interfaces.
FO. 522	shape	uniMorph	This enables multiple shape-changing behaviors with one composite as well as sequential actuation.
FO. 523	shape	uniMorph	Passively shape-changing composites offer interesting possibilities to use this excess energy for shape-actuation with functional and/or aesthetic purposes.
FO. 524	shape	uniMorph	Passively shape-changing composites offer interesting possibilities to use this excess energy for shape-actuation with functional and/or aesthetic purposes.
FO. 525	shape	uniMorph	As seen in figure 2 one simply needs to create a two-layer composite of Kapton and UHMW PE (or other materials with a large difference in thermal expansion) to create a passive shape-changing composite.
FO. 526	shape	uniMorph	Once composited, the sheet can be cut into arbitrary shapes by using digital fabrication tools like vinyl or laser cutters.
FO. 527	shape	uniMorph	For a uniMorph composite to actively change its own shape, it has to change its own temperature.
FO. 528	shape	uniMorph	When designing shape-changing composites with stiffeners (see section primitives), the most determining factor is hinge length, which is defined as the length of the area in between two stiffeners.
FO. 529	shape	uniMorph	The shape-change of uniMorph composites is powered by temperature change.
FO. 530	shape	uniMorph	We define these modes of actuation as active and passive shape-change.
FO. 531	shape	uniMorph	Passive shape-change lacks computational control, but does not require any additional energy.
FO. 532	shape	uniMorph	Active shape-change on the other hand offers very precise and local actuation of the material while requiring energy.
FO. 533	shape	uniMorph	UniMorph composites can be designed for either passive or both passive and active shape-change.
FO. 534	shape	uniMorph	For digital fabrication, the designer generates a digital pattern for the conductive layer as well as the overall shape of the composite using familiar tools like CadSoft's Eagle or Adobe's Illustrator.
FO. 535	shape	uniMorph	Customized uniMorph composites offer a variety of design options for shape-change as seen in Figure 8.
FO. 536	shape	uniMorph	The natural shape-change primitive is bending, which can be modified into curling and twisting.
FO. 537	shape	uniMorph	While passive composite's shape-change is fully determined during its digital fabrication, active composite can change into multiple states since the actuation elements are individually addressable.
FO. 538	shape	uniMorph	As with most active material composites, the range of possible shape-change is defined in the fabrication process.
FO. 539	shape	uniMorph	Designing heating elements of different shapes and distributions leads to new shape-changing behavior.
FO. 540	shape	uniMorph	Designing heating elements of different shapes and distributions leads to new shape-changing behavior.
FO. 541	shape	uniMorph	For heating areas, the traces should go perpendicular to the bending direction to not interfere with the shape-change.
FO. 542	shape	uniMorph	Depending on the area of the heating pattern and shape of the composite, the bending angle and curvatures vary.
FO. 543	shape	uniMorph	While bending and curling have already been used for a wide range of applications, more shape-changing primitives extend the applications for the uniMorph composite.

Código	Palavra-chave	Projeto	Palavra-chave em contexto
FO. 544	shape	uniMorph	In the following section we will show second order shape change primitives that are derived from the basic bending mechanism.
FO. 545	shape	uniMorph	These two actuation primitives can be combined to construct a multitude of dynamic three dimensional shapes out of the sheet composite.
FO. 546	shape	uniMorph	Adding electronic components to shape-changing composites is crucial for building interactive prototypes.
FO. 547	shape	uniMorph	Additional electronic components are often added to shape-changing composites to create effects that are not achievable with just the native qualities of the composite.
FO. 548	shape	uniMorph	Because of their changing shape, these composites make it hard to embed rigid PCBs.
FO. 549	shape	uniMorph	The wiring of the electronics and placing of the components has to be done with the desired shape-change in mind.
FO. 550	shape	uniMorph	The flower lampshade is a dynamic lampshade with the shape and analog behavior of a flower.
FO. 551	shape	uniMorph	This artifact's shape-change is driven solely by the heat dissipated from the light bulb, exemplifying how unimorph structures can be used to inform us about ambient or local temperatures without the need of control circuits or power supplies on the material side.
FO. 552	shape	uniMorph	The materials were composited in large sheets and then laser-cut into shape.
FO. 553	shape	uniMorph	The composite senses its new shape and turns off the light.
FO. 554	shape	uniMorph	In this application, we show a shape-changing iPad cover with the ability to inform and notify a user about the state of the iPad as a form of ambient media and also affords simple interactions.
FO. 555	shape	uniMorph	Further reducing the amount of manual work through automation as well as developing a more sophisticated bonding process would increase the success rates in fabrication and result in higher energy efficiency and force for shape-actuation.
FO. 556	shape	uniMorph	Gaining computational control of other material properties than shape is important for this mission.
FO. 557	shape	uniMorph	Using plastics with a low thermal deposition temperature like polystyrene and thermochromic inks, we envision a more complex composite that would enable shape, stiffness, and color change thin sheet interfaces.
FO. 558	shape	uniMorph	In this paper we presented thin shape-changing materials in small scale.
FO. 559	shape	uniMorph	When designing shape-changing composites, an extensive understanding of the material behavior is needed.
FO. 560	shape	uniMorph	The uniMorph mechanism could be translated into more complex three-dimensional shapes that integrate not only electronic but also complex shape-changing capabilities.
FO. 561	shape	uniMorph	The uniMorph mechanism could be translated into more complex three-dimensional shapes that integrate not only electronic but also complex shape-changing capabilities.
FO. 562	shape	uniMorph	This paper presents a thin-film shape-changing material as an architecture for simple prototyping of dynamic shape-changing artifacts and interfaces.
FO. 563	shape	uniMorph	This paper presents a thin-film shape-changing material as an architecture for simple prototyping of dynamic shape-changing artifacts and interfaces.
FO. 564	shape	uniMorph	The presented uniMorph composite enables passive and active shape-change with integrated control and sensing modalities.
FO. 565	shape	uniMorph	This research serves as an enabling prototyping technique and inspiration for future explorations in thin shape-changing interfaces as well as an encouragement for more work in materially mediated human-computer interaction.
FO. 566	shape	TRANSFORM	"Radical Atoms" is our vision of human interaction with dynamic, computationally reconfigurable and transformable shape-changing materials.

Código	Palavra-chave	Projeto	Palavra-chave em contexto
FO. 567	shape	TRANSFORM	TRANSFORM is comprised of three dynamic shape displays (inFORM) that move over one thousand pins up and down in real-time to reshape the tabletop into a dynamic, tangible display.
FO. 568	shape	TRANSFORM	TRANSFORM is comprised of three dynamic shape displays (inFORM) that move over one thousand pins up and down in real-time to reshape the tabletop into a dynamic, tangible display.
FO. 569	shape	TRANSFORM	TRANSFORM is a custom designed table with 3 embedded inFORM shape displays.
FO. 570	shape	TRANSFORM	While they represent the spirit of Tangible Bits, the clay and sand do not have any memory of shape nor the capability to display dynamic changes, like mountain formations or erosions.
FO. 571	shape	TRANSFORM	They not only afford sculpting with our hands, but the shape can change in real-time using computation as the driving force.
FO. 572	shape	TRANSFORM	The modules can be seamlessly combined to form a larger shape display surface.
FO. 573	shape	TRANSFORM	We created three shape displays, 16 x 24 pins each, covering an area of 406.4 x 610 mm.
FO. 574	shape	TRANSFORM	The shape display hardware uses custom Arduino boards that run a PID controller to sense and move the positions of 6 connected styrene pins through motorized slide potentiometers.
FO. 575	shape	TRANSFORM	The application renders a depth image, which is sent to the shape display over USB to RS485.
FO. 576	shape	TRANSFORM	Given the relative novelty of shape displays as an interaction medium, there are no readily available tools for quick and easy content production.
FO. 577	shape	TRANSFORM	Rendering shapes on TRANSFORM uses 102 x 24 pixel 8 bit gray-scale images, where full white will drive the pin to its highest position and black to its lowest.
FO. 578	shape	TRANSFORM	Although this data format allows us to easily create 2.5D shapes using 2D graphics editors (e.g. Adobe Photoshop, AfterEffects), designing 2.5D motion using only gray scale graphics proved unintuitive and thus inefficient.
FO. 579	shape	TRANSFORM	3ds Max provides all tools necessary to create shapes and animations and displays them on the screen in real-time.
FO. 580	shape	TRANSFORM	Additionally, we created a tool that would display the created 3d shapes on TRANSFORM in real-time using MAXScript.
FO. 581	shape	TRANSFORM	TRANSFORM also demonstrated immense potential of dynamic shape changing materials for artistic expression.
FO. 582	shape	Kinetic Blocks	Pin-based shape displays not only give physical form to digital information, they have the inherent ability to accurately move and manipulate objects placed on top of them.
FO. 583	shape	Kinetic Blocks	In this paper we focus on such object manipulation: we present ideas and techniques that use the underlying shape change to give kinetic ability to otherwise inanimate objects.
FO. 584	shape	Kinetic Blocks	First, we describe the shape display's ability to assemble, disassemble, and reassemble structures from simple passive build- ing blocks through stacking, scaffolding, and catapulting.
FO. 585	shape	Kinetic Blocks	This interplay of the shape display with objects on its surface allows us to render otherwise inaccessible forms, like overhangs, and enables richer input and output.
FO. 586	shape	Kinetic Blocks	However, actuation techniques to move the blocks and computationally rearrange them into shapes have been less researched.
FO. 587	shape	Kinetic Blocks	This idea of dynamic, computer-controlled shapes that form TUIs on demand has been proposed in research visions like Radical Atoms and Claytronics and studied in related fields like modular and swarm robotics.

Código	Palavra-chave	Projeto	Palavra-chave em contexto
FO. 588	shape	Kinetic Blocks	Currently, two approaches for creating dynamic shapes dominate: using shape-changing interfaces, like shape displays, or combining multiple modular elements, like small robots.
FO. 589	shape	Kinetic Blocks	Currently, two approaches for creating dynamic shapes dominate: using shape-changing interfaces, like shape displays, or combining multiple modular elements, like small robots.
FO. 590	shape	Kinetic Blocks	However, both of these approaches have limitations: shape displays can only render certain types of 2.5D shapes, and the engineering challenges of miniaturizing robust modular robots limit their applicability for computer interfaces.
FO. 591	shape	Kinetic Blocks	However, both of these approaches have limitations: shape displays can only render certain types of 2.5D shapes, and the engineering challenges of miniaturizing robust modular robots limit their applicability for computer interfaces.
FO. 592	shape	Kinetic Blocks	We therefore propose combining these two approaches by arranging passive modular building blocks using an underlying shape display.
FO. 593	shape	Kinetic Blocks	This technique simplifies the modular blocks in comparison to miniaturized robots while enabling more degrees of freedom for shape rendering and interaction than do current shape displays.
FO. 594	shape	Kinetic Blocks	This technique simplifies the modular blocks in comparison to miniaturized robots while enabling more degrees of freedom for shape rendering and interaction than do current shape displays.
FO. 595	shape	Kinetic Blocks	Current shape displays use an array of vertically moving pins to render different shapes and forms
FO. 596	shape	Kinetic Blocks	Current shape displays use an array of vertically moving pins to render different shapes and forms
FO. 597	shape	Kinetic Blocks	This method has inherent limitations on the types of shapes that can be generated: in general only 2.5D shapes that go straight up or are tapered towards the top are possible.
FO. 598	shape	Kinetic Blocks	This method has inherent limitations on the types of shapes that can be generated: in general only 2.5D shapes that go straight up or are tapered towards the top are possible.
FO. 599	shape	Kinetic Blocks	The rendered shapes are also constrained to the shape display and cannot be lifted off, limiting how users can interact with them.
FO. 600	shape	Kinetic Blocks	The rendered shapes are also constrained to the shape display and cannot be lifted off, limiting how users can interact with them.
FO. 601	shape	Kinetic Blocks	As the individual pins of the shape display only possess a single degree of freedom (DOF) through vertical movement, they cannot apply lateral forces to passive objects placed on top.
FO. 602	shape	Kinetic Blocks	We de- scribe and evaluate techniques for the constructive assembly of simple, unpowered building blocks into 3D structures via a shape display.
FO. 603	shape	Kinetic Blocks	These structures extend the shape display's rendering capabilities, and allow for expressive user input.
FO. 604	shape	Kinetic Blocks	We also present unpowered kinematic blocks that can be driven and sensed through the underlying shape display.
FO. 605	shape	Kinetic Blocks	These blocks translate the pins' vertical DOF to other DOFs to extend possibilities for shape display input and output or provide special capability like extending pin length to construct higher structures.
FO. 606	shape	Kinetic Blocks	We introduce the idea of a shape display as an interactive and dynamic physical control engine.
FO. 607	shape	Kinetic Blocks	However, these tabletop systems are not designed for constructing shapes out of tokens and are unable to stack them on top of each other.
FO. 608	shape	Kinetic Blocks	Previous shape displays propose rendering information through physical shapes and inFORM investigates constraining and moving physical objects through shape change.

Código	Palavra-chave	Projeto	Palavra-chave em contexto
FO. 609	shape	Kinetic Blocks	Previous shape displays propose rendering information through physical shapes and inFORM investigates constraining and moving physical objects through shape change.
FO. 610	shape	Kinetic Blocks	Physical Telepresence extends this approach to enables the remote handling of objects through the user's body shape.
FO. 611	shape	Kinetic Blocks	Festo Wave Handling proposes object movement through shape actuation for factory automation.
FO. 612	shape	Kinetic Blocks	Modular robots use motorized hinges or internal flywheels to self-arrange spatially into their target shape.
FO. 613	shape	Kinetic Blocks	In contrast to the presented prior work, we try to open a new design space using actuated and self-reconfiguring 3D shapes for tangible interaction.
FO. 614	shape	Kinetic Blocks	In this section we describe our design criteria, the building blocks we use, and the various techniques that enable actuated constructive assembly on shape displays.
FO. 615	shape	Kinetic Blocks	Unlike systems for additive manufacturing and modular robotics, our setup is guided by the principle that the user should be able to interact with the system at any point, even while it assembles a shape.
FO. 616	shape	Kinetic Blocks	No mechanisms like robot arms should be mounted above the shape to avoid colliding with a user's hands.
FO. 617	shape	Kinetic Blocks	We explored constructive assembly on shape displays with both non-locking and locking (magnetic) building blocks.
FO. 618	shape	Kinetic Blocks	On the inFORM shape display they cover a 4 x 4 area of pins.
FO. 619	shape	Kinetic Blocks	At 90 g each, the blocks are light enough for the inFORM to easily lift four vertically-stacked blocks while heavy enough that control of the blocks is maintained through sudden changes on the underlying shape display.
FO. 620	shape	Kinetic Blocks	We also created building blocks that magnetically connect. Constructions composed of these blocks are more permanent, retaining their shape when taken off the shape display, but they can be easily reassembled by users' hands.
FO. 621	shape	Kinetic Blocks	We also created building blocks that magnetically connect. Constructions composed of these blocks are more permanent, retaining their shape when taken off the shape display, but they can be easily reassembled by users' hands.
FO. 622	shape	Kinetic Blocks	The inFORM shape display consists of 30 x 30 motorized pins that cover an area of 381 X381mm.
FO. 623	shape	Kinetic Blocks	The general ability of pin-based shaped displays to move and rotate objects of different size and shape has already been described by prior work.
FO. 624	shape	Kinetic Blocks	The general ability of pin-based shaped displays to move and rotate objects of different size and shape has already been described by prior work.
FO. 625	shape	Kinetic Blocks	While this does not constitute a comprehensive exploration of the design space of constructive assembly on shape displays, we are confident in having identified many of the best techniques afforded by systems like ours.
FO. 626	shape	Kinetic Blocks	Since 2.5D shape displays cannot laterally push objects, we move a rectangular or cubical object across the surface by creating a ramp sloped at 45 degrees.
FO. 627	shape	Kinetic Blocks	Because we cannot create lateral forces on a shape display, rotation around a block's z-axis requires x-y-x or y-x-y compound rotations.
FO. 628	shape	Kinetic Blocks	We can use the shape display's pins to create temporary scaffolds that assist in assembly tasks.
FO. 629	shape	Kinetic Blocks	In this section, we introduce the idea of using a shape display as a computational physical control engine to drive special unpowered kinematic blocks.
FO. 630	shape	Kinetic Blocks	The shape display's pins provide the required input energy to drive the kinematic blocks.
FO. 631	shape	Kinetic Blocks	We imagine the shape displays of the future will control a multitude of kinematic blocks to assist in accomplishing various kinds of physical assembly tasks and provide richer input capabilities

Código	Palavra-chave	Projeto	Palavra-chave em contexto
FO. 632	shape	Kinetic Blocks	As a proof of concept we created four kinematic blocks that are controlled by the underlying shape display.
FO. 633	shape	Kinetic Blocks	We selected block functionalities demonstrating the shape display's ability to control mechanical systems that can overcome the display's inherent limitations.
FO. 634	shape	Kinetic Blocks	These functionalities address the shape display's limited pin height and its lack of overhangs, rotational movement, and lateral movement.
FO. 635	shape	Kinetic Blocks	The Extender gives us the ability to extend the shape display's pin height.
FO. 636	shape	Kinetic Blocks	The Extender is placed on top of the shape display such that the underlying display's pins can push against the Extender's pins.
FO. 637	shape	Kinetic Blocks	It covers an area of 4 x 4 pins on the shape display.
FO. 638	shape	Kinetic Blocks	The shape display can fold the flaps back in by pressing a lever that folded out with the flaps.
FO. 639	shape	Kinetic Blocks	We can use the Rotator as input device as well, providing a new degree of freedom for interaction with shape displays.
FO. 640	shape	Kinetic Blocks	The shape display automatically assembles the selected structure using seven locking blocks.
FO. 641	shape	Kinetic Blocks	Once the first structure is assembled and another is selected, the shape display will disassemble the current structure and reassemble the blocks to match the newly selected structure.
FO. 642	shape	Kinetic Blocks	The user creates a structure from building blocks locally. The remote shape display follows the user's movements and assembles the structure ad hoc.
FO. 643	shape	Kinetic Blocks	The remote shape display system determines the optimal path and assembly technique for replicating the remote structures and build them whole-sale.
FO. 644	shape	Kinetic Blocks	In a similar fashion we use the Slider to move a building block from left to right direction across the shape display.
FO. 645	shape	Kinetic Blocks	Such a system would be similar in shape to previously proposed block-based CAD interfaces by Aish et al.
FO. 646	shape	Kinetic Blocks	For tracking the blocks' positions for remote-assembly we used a Microsoft Kinect depth camera mounted above the shape display.
FO. 647	shape	Kinetic Blocks	We crop the input image to fit the shape display, use depth and color information to determine the height of the stacked structure, and apply contour recognition to detect whether a user is grasping a block.
FO. 648	shape	Kinetic Blocks	Most research findings presented in this paper are tailored towards the inFORM shape display and future systems with different form factors or technical specifications might enable different assembly techniques.
FO. 649	shape	Kinetic Blocks	This could mean embedding sensors in the shape display's pins or implementing more sophisticated computer vision techniques.
FO. 650	shape	Kinetic Blocks	In this paper, we focused on cube-shaped building blocks.
FO. 651	shape	Kinetic Blocks	We plan to explore actuated constructive assembly with more diverse shapes like cylinders or triangular objects.
FO. 652	shape	Kinetic Blocks	A long- term goal is for shape displays to assemble arbitrary objects.
FO. 653	shape	Kinetic Blocks	One could imagine placing screws, gears and levers on the shape display to have it assemble a mechanical tool it could use for further tasks.
FO. 654	shape	Kinetic Blocks	Using active blocks in combination with the shape display opens another interesting realm.
FO. 655	shape	Kinetic Blocks	The shape display's pins could have conductive connectors providing external electrical power to the blocks.
FO. 656	shape	Kinetic Blocks	The shape display's size limits the number of building blocks we can handle at once.
FO. 657	shape	Kinetic Blocks	Higher resolution shape displays could enable constructive assembly with smaller building blocks and allow the construction of more detailed structures.

Código	Palavra-chave	Projeto	Palavra-chave em contexto
FO. 658	shape	Kinetic Blocks	The kinematic blocks controlled by the inFORM shape display were too weak to reliably assist in actuated assembly scenarios.
FO. 659	shape	Kinetic Blocks	The ability to move kinematic blocks on the shape display out of the way or to a required position is necessary for general-purpose unaided construction with them.
FO. 660	shape	Kinetic Blocks	We will also explore more complex applications for using shape displays with kinematic blocks to manipulate physical objects.
FO. 661	shape	Kinetic Blocks	In this paper we presented actuated constructive assembly, disassembly and reassembly with passive building blocks on pin-based shape displays.
FO. 662	shape	Kinetic Blocks	We introduced special kinematic blocks that can be driven and sensed through the shape display and that extend its degrees of freedom for both output and input.
FO. 663	shape	Kinetic Blocks	We provided evidence that shape displays can serve as interactive dynamic physical control engines for a range of assembly tasks.
FO. 664	shape	ChainFORM	This paper presents ChainFORM: a linear, modular, actuated hardware system as a novel type of shape changing interface.
FO. 665	shape	ChainFORM	Leveraging the modular functionality, we introduce novel interaction capability with shape changing interfaces, such as rearranging the shape/configuration and attaching to passive objects and bodies.
FO. 666	shape	ChainFORM	Leveraging the modular functionality, we introduce novel interaction capability with shape changing interfaces, such as rearranging the shape/configuration and attaching to passive objects and bodies.
FO. 667	shape	ChainFORM	As shape changing interfaces being an emerging field in HCI, a lot of actuation techniques have been introduced to provide physical shapes to represent digital data and to embody spatial interactions.
FO. 668	shape	ChainFORM	As shape changing interfaces being an emerging field in HCI, a lot of actuation techniques have been introduced to provide physical shapes to represent digital data and to embody spatial interactions.
FO. 669	shape	ChainFORM	To extend the sensing and display capability of such shape changing interfaces, extra sensors or cameras and projectors have been installed for detecting human input and displaying information on the active surfaces.
FO. 670	shape	ChainFORM	To push the boundaries of shape-changing interface research, another approach calls for self-contained systems that integrate sensing, actuation and display across different scales, geometries, and transformations.
FO. 671	shape	ChainFORM	The form-factor of line and the modularity expands the possibility of transformation for both shapes and scales.
FO. 672	shape	ChainFORM	Our approach is a step toward a general platform for custom shape-changing interfaces.
FO. 673	shape	ChainFORM	Building on the idea and implementation of modular and serpentine robotics, we intend to extend their knowledge and technique to enrich interactions with shape-changing interfaces.
FO. 674	shape	ChainFORM	We developed a modular shape changing interface system which has a linear configuration.
FO. 675	shape	ChainFORM	The module connect together to form an arbitrary linear shape using mechanical joints and electrical communication architecture.
FO. 676	shape	ChainFORM	We implemented a variety of application scenarios for shape changing computer interfaces and actuated prototyping tools.
FO. 677	shape	ChainFORM	SensorTape has the form factor of tape that user can cut and arrange the length and shape of the sensor array using flexible circuit boards with a chained communication system design.
FO. 678	shape	ChainFORM	Another work demonstrates block-like interface, that automatically detected changes in shape.



Código	Palavra-chave	Projeto	Palavra-chave em contexto
FO. 679	shape	ChainFORM	Various concepts and methods of shape changing interfaces have been presented recently in the field of HCI to render physical shape of digital data and provide dynamic affordance for physical interactions.
FO. 680	shape	ChainFORM	Various concepts and methods of shape changing interfaces have been presented recently in the field of HCI to render physical shape of digital data and provide dynamic affordance for physical interactions.
FO. 681	shape	ChainFORM	ShapeClip is a prototyping tool that is composed of linear actuated modules for constructing customized shape displays.
FO. 682	shape	ChainFORM	ShapeClip is a prototyping tool that is composed of linear actuated modules for constructing customized shape displays.
FO. 683	shape	ChainFORM	Within the HCI field, there have also been proposed various types of tangible interfaces which have form factor of lines. ShapeTape was introduced as a passive 3D modeling tool that leveraging the flexibility and affordance of a spline.
FO. 684	shape	ChainFORM	Katsumoto et al. presented a bi-stable geometries for a controller composed with chained mechanical hinges and proposed applications that provide different digital functions according to shapes.
FO. 685	shape	ChainFORM	As a novel form of shape changing interfaces, LineFORM introduced the concept of actuated curve interface leveraging the dynamic transformation capability and tangible interaction of lines.
FO. 686	shape	ChainFORM	Leveraging the capability, users can rearrange the configuration of the device to create desired shape and transformation.
FO. 687	shape	ChainFORM	...read the input of internal potentiometer values and to control the connection of the wire to the motor so that the motor axis can either be flexible for manual control or actuated(stiff) for transforming and locking shape.
FO. 688	shape	ChainFORM	As the software receives potentiometer values, it can estimate the whole shape of the device and location of each LED.
FO. 689	shape	ChainFORM	Using this function on the software, users only need to write codes on visualization such as shapes, texts or loaded images which are default functions for Processing.
FO. 690	shape	ChainFORM	We developed a function for shape and motion design.
FO. 691	shape	ChainFORM	For chain-based hardware design, it is complicated to generate target shape and motion by coding because users need to define an angle for each module to get the whole shape.
FO. 692	shape	ChainFORM	Similar to Topobo, the shape and motion can be recorded based on the potentiometer values and replayed back anytime.
FO. 693	shape	ChainFORM	Non- programmers can easily design motion without programming, and programmers can develop interaction system to replay these shapes and motions according to specific input data from sensors.
FO. 694	shape	ChainFORM	This category includes three applications; adaptive input interface, shape changing modular display, and shape changing stylus.
FO. 695	shape	ChainFORM	This category includes three applications; adaptive input interface, shape changing modular display, and shape changing stylus.
FO. 696	shape	ChainFORM	Utilizing the LED arrays on each module, ChainFORM can construct displays in various shapes.
FO. 697	shape	ChainFORM	Although a lot of systems for shape changing flexible displays have been proposed, they mostly consist of rectangular surfaces that can create slight curves.
FO. 698	shape	ChainFORM	In contrast, our chained hardware system has more dynamic transformation capability to create shapes either in 2D or 3D.

Código	Palavra-chave	Projeto	Palavra-chave em contexto
FO. 699	shape	ChainFORM	Using our display technology, we can imagine a future smartphone that can change shape from rectangular shapes to present texts or pass cord lock information, to circle shapes for navigating users as a compass.
FO. 700	shape	ChainFORM	Using our display technology, we can imagine a future smartphone that can change shape from rectangular shapes to present texts or pass cord lock information, to circle shapes for navigating users as a compass.
FO. 701	shape	ChainFORM	Using our display technology, we can imagine a future smartphone that can change shape from rectangular shapes to present texts or pass cord lock information, to circle shapes for navigating users as a compass.
FO. 702	shape	ChainFORM	Similar to smart watches that can change the visual skin, our system can inform time in various shapes and appearance according to users' preferences.
FO. 703	shape	ChainFORM	Our proposed stylus interface transforms the physical shape of tool tip instantly once users change gripping.
FO. 704	shape	ChainFORM	Just like using traditional linear craft material such as wires or tapes, the user can deform, cut, connect and attach to other materials to construct their own shapes and motions.
FO. 705	shape	ChainFORM	Leveraging the customizing and attaching capability, the ChainFORM system enables users to construct customized body augmentation devices, as our bodies have different size and shapes.
FO. 706	shape	ChainFORM	This kind of application lets users customize length or shape of the device that represents abstract information, then observe behavior through their transformation to learn algorithms or underlying abstract ideas.
FO. 707	shape	Cilllia	The ability to fabricate customized hair-like structures not only expands the library of 3D-printable shapes, but also enables us to design passive actuators and swipe sensors.
FO. 708	shape	Cilllia	Most of the current commercially available 3D printers use a layer-by-layer method to deposit/solidify materials into shapes that are designed in the CAD.
FO. 709	shape	Cilllia	This method gives us the highest resolution control of the printed cone shape.
FO. 710	shape	Cilllia	We can also generate curved hair by offsetting the pixel group in a spiral layer by layer. Figure 6 shows a spring shape hair.
FO. 711	shape	Cilllia	However, we discovered that as one increases the exposure time, the polymerized dot formed into a long oval instead of circle shape.
FO. 712	shape	Cilllia	This is due the shape distortion of laser beam.
FO. 713	shape	Cilllia	With the color mapping method, one could create more complex shape of a brush for artistic expression.
FO. 714	shape	Cilllia	Recent research on actuated tangible interfaces, especially soft shape-change interfaces has shown that by carefully designing material structures, one can achieve compelling shape-change with one single actuator.
FO. 715	shape	Cilllia	Recent research on actuated tangible interfaces, especially soft shape-change interfaces has shown that by carefully designing material structures, one can achieve compelling shape-change with one single actuator.
FO. 716	shape	Cilllia	After printing, we manually glued them back into the original shape.
FO. 717	shape	Cilllia	The block can actuate a cylinder shaped material when the vibration is applied.
FO. 718	shape	Cilllia	Swipes against the grain (labeled as backwards) produce a flatter spectrum—closer to noise in the time domain—whose profile is shaped by the speed of the swipe...
FO. 719	shape	Cilllia	For example, if we had to create an arbitrarily shaped object that is fully covered by hair, we would have to split the object so that the curvature of the surface can still be printed without a supporting structure.

Código	Palavra-chave	Projeto	Palavra-chave em contexto
FO. 720	shape	Cillia	The ability to fabricate customized hair-like structures not only expands the library of 3D-printable shapes, but also enables us to design alternative actuator and sensors.
FO. 721	shape	Materiable	Shape changing interfaces give physical shapes to digital data so that users can feel and manipulate data with their hands and bodies.
FO. 722	shape	Materiable	Shape changing interfaces give physical shapes to digital data so that users can feel and manipulate data with their hands and bodies.
FO. 723	shape	Materiable	However, physical objects in our daily life not only have shape but also various material properties.
FO. 724	shape	Materiable	In this paper, we propose an interaction technique to represent material properties using shape changing interfaces.
FO. 725	shape	Materiable	As a proof-of-concept prototype, we developed preliminary physics algorithms running on pin-based shape displays.
FO. 726	shape	Materiable	In our experiments, users identify three deformable material properties (flexibility, elasticity and viscosity) through direct touch interaction with the shape display and its dynamic movements.
FO. 727	shape	Materiable	Our research shows that shape changing interfaces can go beyond simply displaying shape allowing for rich embodied interaction and perceptions of rendered materials with the hands and body.
FO. 728	shape	Materiable	Shape changing interfaces have been a recent realm of research in the HCI field.
FO. 729	shape	Materiable	Shapes of 3D digital data or even remote real objects can be rendered and manipulated in physical form, dynamically using various types of shape changing interfaces.
FO. 730	shape	Materiable	Shapes of 3D digital data or even remote real objects can be rendered and manipulated in physical form, dynamically using various types of shape changing interfaces.
FO. 731	shape	Materiable	While shape, color and animation of objects allows us rich physical and dynamic affordances, our physical world can afford material properties that are yet to be explored by such interfaces.
FO. 732	shape	Materiable	Material properties of shape changing interfaces are currently limited to the material that the interface is constructed with.
FO. 733	shape	Materiable	How can we represent various material properties by taking advantage of shape changing interfaces' capability to allow direct, complex and physical human interactions?
FO. 734	shape	Materiable	In this paper, we explore methods to represent dynamic human perceivable material properties through shape changing interfaces, where the shape and nature of the material is directly deformed by the user.
FO. 735	shape	Materiable	In this paper, we explore methods to represent dynamic human perceivable material properties through shape changing interfaces, where the shape and nature of the material is directly deformed by the user.
FO. 736	shape	Materiable	Specifically, by controlling the shape of interface according to users' direct physical input, we assume that users can perceive of various material properties through physical deformation.
FO. 737	shape	Materiable	We implemented two main types of material emulations, deformable solid and liquid, using basic physics simulation algorithms on a pin-based shape display in combination with direct physical input detection algorithms.
FO. 738	shape	Materiable	We propose application's that utilize the display's ability to render multiple material properties at the same time, or to render shapes in response to input.
FO. 739	shape	Materiable	Also, recent 3D printing research enables us to replicate objects to have both various shapes and elasticity by controlling their micro structures.

Código	Palavra-chave	Projeto	Palavra-chave em contexto
FO. 740	shape	Materiable	In contrast to prior work, we introduce a novel interaction technique to represent material properties with shape changing interfaces inspired by pseudo haptic effect, which changes shape according to the direct manipulation from the user.
FO. 741	shape	Materiable	In contrast to prior work, we introduce a novel interaction technique to represent material properties with shape changing interfaces inspired by pseudo haptic effect, which changes shape according to the direct manipulation from the user.
FO. 742	shape	Materiable	With this technique, we aim to push the capability of shape changing interfaces beyond shapes even if they are composed with a single material.
FO. 743	shape	Materiable	With this technique, we aim to push the capability of shape changing interfaces beyond shapes even if they are composed with a single material.
FO. 744	shape	Materiable	Elasticity is a measure for a materials ability to resist a distorting influence or stress and to return to its original size and shape when the stress is removed.
FO. 745	shape	Materiable	In this paper we attempt to measure the displacement of a user's direct manipulation as touch input, translate this through physics emulations and have the shape changing interface render a dynamic deformable solid or liquid that behaves relative to the calculated physics of this input.
FO. 746	shape	Materiable	Thus, our proposed approach enables shape changing interfaces to represent dynamic shapes and material properties at the same time.
FO. 747	shape	Materiable	The shape changing interface detects the user's direct physical input using built-in sensors and changes its overall shape with actuators according to a physics emulation that is computed in real time.
FO. 748	shape	Materiable	The shape changing interface detects the user's direct physical input using built-in sensors and changes its overall shape with actuators according to a physics emulation that is computed in real time.
FO. 749	shape	Materiable	To interact with the rendered material on shape changing interfaces, a user can use any part of their body to touch and manipulate the rendered material property as shown in Figure 3.
FO. 750	shape	Materiable	As a proof of concept, we implemented a prototype system to represent material properties using two pin-based shape displays.
FO. 751	shape	Materiable	TRANSFORM system consists of three shape displays, 16 → 24 pins each, which extend up to 100 mm from the surface, and cover an area of 406 → 610 mm.
FO. 752	shape	Materiable	The shape display hardware uses custom Arduino boards that run a PID controller to sense and move the positions polystyrene pins through motorized slide potentiometers.
FO. 753	shape	Materiable	We developed application examples on a smaller shape display consisting of 24 → 24 actuated pins on a 434 → 434 mm area.
FO. 754	shape	Materiable	This shape display also has a projector mounted to provide graphic feedback on top of the surface of pins.
FO. 755	shape	Materiable	Certain material properties are simulated in the emulator, then the output shape data is sent to both the shape display and the touch detector.
FO. 756	shape	Materiable	Certain material properties are simulated in the emulator, then the output shape data is sent to both the shape display and the touch detector.
FO. 757	shape	Materiable	While the shape display renders the shape, it detects the measured height at the same time and passes it to the touch detector.
FO. 758	shape	Materiable	Each grid cell in the model maps to a pin on the shape display.

Código	Palavra-chave	Projeto	Palavra-chave em contexto
FO. 759	shape	Materiable	Each mode has its heights rescaled and translated in order to meet the 0 to 255 value range of the shape display's input value for pin height.
FO. 760	shape	Materiable	For input from the touch detector (described later), an impulse value is added to the shape display's touched pin's corresponding cell's velocity.
FO. 761	shape	Materiable	In this section, we demonstrate possible applications that utilize the capability of our technique to render dynamic shapes and material properties at the same time on shape changing interfaces; a pin-based shape display in this case.
FO. 762	shape	Materiable	In this section, we demonstrate possible applications that utilize the capability of our technique to render dynamic shapes and material properties at the same time on shape changing interfaces; a pin-based shape display in this case.
FO. 763	shape	Materiable	In this section, we demonstrate possible applications that utilize the capability of our technique to render dynamic shapes and material properties at the same time on shape changing interfaces; a pin-based shape display in this case.
FO. 764	shape	Materiable	With rendered material properties in combination with the ability to directly manipulate 3D shapes, novice users can create and simulate land formations in the same way they might play with the materials usually used to create models.
FO. 765	shape	Materiable	These material properties, if emulated in shape changing interfaces, could prove useful for enhancing the way we interact with physical data.
FO. 766	shape	Materiable	For each experiment, users were told to focus on their observations of what they see while interacting with the shape display.
FO. 767	shape	Materiable	Most participants vocalized the difficulty of rating flexibility due to the way they had to interact with the shape display pushing with a downwards force which is not an interaction they are used to doing with real world deformable solid materials.
FO. 768	shape	Materiable	Due to 2.5D movement on current shape displays, some simulated material properties are easier to identify than others.
FO. 769	shape	Materiable	Not all material properties will make sense to simulate on shape displays, for example, any form of gas would be extremely difficult.
FO. 770	shape	Materiable	A deformable solid material is usually grasped to gauge its flexibility, not pushed, however we had to make do with the limitation of the shape displays vertical displacement.
FO. 771	shape	Materiable	Due to this, we are interested in trying different implementations on alternative shape changing interfaces in future work.
FO. 772	shape	Materiable	We are also limited by the type of sensing and actuators we have built into our current shape displays.
FO. 773	shape	Materiable	...notable also in the way many users simply did not look at the shape display while trying to answer our questions. In addition to this, participants were shown how to interact
FO. 774	shape	Materiable	While everything in this paper is stated as a simulation, this behavior suggests that directly manipulating a real-world physical form that changes shape, regardless of its underlying computation, for the individual, appears to be a very real and physical experience.
FO. 775	shape	Materiable	Additionally, shape display actuators with higher maximum torque would make it possible to render varied force feedback.
FO. 776	shape	Materiable	Although the surface texture on our implementation was polystyrene, improving the resolution of shape display could provide fine tactile feedback.
FO. 777	shape	Materiable	We have proposed a method to render variable deformable material properties through transformation and direct manipulation using shape changing interfaces.
FO. 778	shape	Materiable	We introduced our prototype with preliminary physics algorithms on a pin-based shape display.

Código	Palavra-chave	Projeto	Palavra-chave em contexto
FO. 779	shape	Materiable	We envision a future for shape changing interfaces where rendered materials can be recognized by their perceived material properties, directly manipulated and used in applications to enable rich new experiences with digital information.